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5 **SYSTEM FOR VISUALIZING PATIENT STRESS**

FIELD OF THE INVENTION

The present application relates generally to a method, a system and computer readable
10 storage media for visualizing patient stress and, more particularly, to a method,
system and computer readable storage media for visualizing a patient's changing
stress conditions during treatment such that a clinician may adopt mitigative measures
in order to improve the patient's experience.

15 **BACKGROUND OF THE INVENTION**

Various options exist for treating dental defects such as by the use of restorations as
well as the placement of dental implants using physical guides/sleeves and
restorations to restore tooth functions.

20 Clinicians may create a treatment plan and use dental instruments such as dental
drills, dental lasers, and endodontic instruments to provide treatment. During such
treatments, the patient may experience varying degrees of pain or discomfort based
on, for example, tooth sensitivity and proximity of a treatment area to nerves/blood
25 vessels. A patient experiencing pain may not be able to easily express such pain due
to his/her buccal cavity being held open for treatment purposes. Clinicians may ask
the patient to nod their heads, raise their hand, tap on the clinician, etc. if experiencing
pain. However, this manual process may be inefficient as treatments usually require a
patient to be still. Moreover, a focused clinician may not notice such gestures in time.
30 There is therefore a need to automatically provide information about changing patient
stress/discomfort to a clinician in a view direction or vicinity of the clinician in order
for the clinician to adapt accordingly and improve patient experience without having
to monitor a device that is out of view or reach.

35 European Patent EP0748611A2 discloses a heart function monitoring system applied
to dental apparatus such as dental units consisting of a base supporting a first column,

5 placed beside a chair, and a first main holder for dental instruments; there being also envisaged on the said dental unit a plurality of sensors designed to detect an electrocardiographic signal, applied to parts of the body of a patient and forming part of an electrocardiograph. It is incorporated by reference for background disclosure purposes.

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U.S. Patent Application Number 15,656,701 discloses a notification system for providing feedback from a patient to a dentist, the system including a notification panel mounted in proximity to a dental chair and an activation device. The activation device may be a hand-held device, such as a wireless remote, or may be mounted near
15 the dental chair. The activation device may include one or more switches for activation by the patient. Each switch may correspond to a condition being experienced by the patient, such as pain, discomfort, or the need for suction. During a dental procedure, the switches may be activated by the patient to request a corresponding action by the dentist.

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US Patent Application Number 14,977,258 discloses a Mobile Dental Intelligence Center (MobiDIC) that may roll up alongside a patient's Bedside or Chairside where oral hygiene may be performed by the patient's caregiver, with no need to have a sink or basin in the area. Using the MobiDIC the caregiver may be able to brush the
25 patient's teeth, rinse and suction the patient's mouth as well as monitor the patients Vital Signs.

US Patent Application No. 2017202633 discloses an imaging and display system for guiding medical interventions comprising a wearable display for viewing by a user
30 wherein the display presents a composite, or combined image that includes pre-operative surgical navigation images, intraoperative images, and in-vivo microscopy images or sensing data. A probe, such as a microscopy probe or a sensing probe, may be used to acquire in-vivo imaging/sensing data from the patient and the intra-operative and in-vivo images may be acquired using tracking and registration
35 techniques to align them with the pre-operative image and the patient to form a composite image for display.

5 US Patent Application No. 20020082498 discloses a method for image-guided surgery comprising capturing 3-dimensional (3D) volume data of a portion of a patient, processing the volume data so as to provide a graphical representation of the data, capturing a stereoscopic video view of a scene including a portion of said patient, rendering the graphical representation and the stereoscopic video view in a
10 blended manner so as to provide a stereoscopic augmented image, and displaying said stereoscopic augmented image in a video-see-through display.

US Patent Application Publication No. 20160191887 describes a real-time surgery navigation method and apparatus for displaying an augmented view of a patient from
15 a static or dynamic viewpoint of a surgeon. A surface image, a graphical representation of the internal anatomic structure of the patient processed from preoperative or intraoperative images, and a computer geometrically registering both images may be used. Responsive to geometrically registering the images, a head
mounted display may present to a surgeon an augmented view of the patient.

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SUMMARY OF THE INVENTION

Existing limitations associated with the foregoing, as well as other limitations, can be overcome by the system according to claim 1 for the visualization of patient stress
25 during treatment.

In an aspect herein, the present invention provides a method utilizing augmented visualization, the method comprising: providing a biopotential sensor system adapted to retrieve patient biopotential information; obtaining said patient biopotential
30 information from the biopotential sensor; analyzing said patient biopotential information to obtain a treatment regimen; and overlaying the patient biopotential information and/or the treatment regimen as an augmentation on a predetermined site through an augmented reality device such that the patient biopotential information appears directly superimposed on said predetermined site.

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In another aspect herein, the method further comprises one or more of the steps: (i) further comprising analyzing the patient biopotential information to obtain a change in

5 the patient biopotential information by comparing a first biopotential data
corresponding to the patient's stress/discomfort level at a first time period to a
biopotential data corresponding to the patient's stress/discomfort level at a second
time period, (ii) wherein the first time period is a time period selected before
treatment begins and the second time period is a time period selected after treatment
10 begins, (iii) further comprising providing the treatment regimen based on said change
in the patient biopotential information, (iv) wherein said predetermined site is a site
selected from the group consisting of the patient, a region of the patient, or site in a
field of view of a user of the augmented reality device, (v) wherein said patient
biopotential information is obtained in real-time, (vi) wherein said patient biopotential
15 information includes information selected from the group consisting of heart rate,
blood volume pulse, cortisol levels in sweat, a signal that corresponds to the patient's
heart rate and a signal that corresponds to a stress level of the patient, (vii) further
comprising; updating the augmentation based on data selected from the group
consisting of (a) real time data tracking changes in patient biopotential information (b)
20 real time data tracking clinician movements and (c) real time data tracking patient
movements.

In another aspect, a system is provided, the system utilizing augmented visualization,
the system comprising; an augmented reality device, a biopotential sensor system
25 adapted to retrieve patient biopotential information; and at least one processor
configured to perform the steps of; obtaining said patient biopotential information
from the biopotential sensor; analyzing said patient biopotential information to obtain
a treatment regimen; and overlaying the patient biopotential information and/or the
treatment regimen as an augmentation on a predetermined site through the augmented
30 reality device such that the patient biopotential information appears directly
superimposed on said predetermined site.

In another aspect herein, the system further comprises one or more of the
configurations: (i) further comprising tracking system configured to offer real-time
35 position data for a precise location, orientation and update of patient biopotential data
and/or treatment regimen in a common coordinate system, (ii) wherein the tracking
system is sensor based and/or vision based, (iii) wherein the biopotential sensor

- 5 system includes an electrode sensor, a cortisol measuring sensor and/or a sensor that provides a signal that is the patient's heart rate or corresponds to the patient's heart rate or stress level, (iv) wherein the processor is further configured to: analyze the patient biopotential information to obtain a change in the patient biopotential information by comparing a first biopotential data corresponding to the patient's
- 10 stress/discomfort level at a first time period to a biopotential data corresponding to the patient's stress/discomfort level at a second time period, (v) wherein the first time period is a time period selected before treatment begins and the second time period is a time period selected after treatment begins, (vi) further comprising providing the treatment regimen based on said change in the patient biopotential information, (vii)
- 15 wherein said predetermined site is a site selected from the group consisting of the patient, a region of the patient, or site in a field of view of a user of the augmented reality device, (viii) wherein said patient biopotential information is obtained in real-time, (ix) wherein said patient biopotential information includes information selected from the group consisting of heart rate, blood volume pulse, cortisol levels in sweat, a
- 20 signal that corresponds to the patient's heart rate and a signal that corresponds to a stress level of the patient, (x) wherein the processor is further configured to perform the step of; updating the augmentation based on data selected from the group consisting of (a) real time data tracking changes in patient biopotential information (b) real time data tracking clinician movements and (c) real time data tracking patient
- 25 movements, (x) wherein the biopotential sensor system is a handheld device through which the patient manually registers his/or pain sensations and/or stress levels (xi) wherein the biopotential information and/or the treatment regimen are displayed on a mobile device, e.g. an iPad.
- 30 In yet another aspect, a method is provided, the method comprising: providing a biopotential sensor system adapted to retrieve patient biopotential information; obtaining said patient biopotential information from the biopotential sensor; analyzing said patient biopotential information to obtain a treatment regimen; and providing the patient biopotential information and/or the treatment as a visual, auditory or haptic
- 35 output.

5 In even yet another aspect, a non-transitory computer-readable storage medium is provided, the non-transitory computer-readable storage medium storing a program which, when executed by a computer system, causes the computer system to perform a procedure comprising: providing a biopotential sensor system adapted to retrieve patient biopotential information; obtaining said patient biopotential information from
10 the biopotential sensor; analyzing said patient biopotential information to obtain a treatment regimen; and overlaying the patient biopotential information and/or the treatment regimen as an augmentation on a predetermined site through an augmented reality device such that the patient biopotential information appears directly superimposed on said predetermined site.

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BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments will become more fully understood from the detailed description given herein below and the accompanying drawings, wherein:

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FIG. 1 is a block diagram illustrating a visualization system according to an embodiment of the present invention;

FIG. 2 illustrates a perspective view of a dental chair according to an exemplary computer system according to an embodiment of the present invention;

25 FIG. 3 illustrates a block diagram showing a computer system of the present invention;

FIG. 4 is a flow chart showing a method according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

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In accordance with example aspects described herein, a method, system and computer readable storage media is provided for visualizing a patient's stress level using augmented reality and adopting mitigative measures in order to improve patient
35 experience.

5 *System for Visualizing Patient Stress*

FIG. 1 illustrates a visualization system 1 comprising a display device 12 for augmented visualization such as head mounted augmented reality glasses, an HUD display, or a stereoscopic display capable of receiving stereoscopic video images, or
10 otherwise display device 12 that may be used for overlaying patient biopotential information 42 (such as, for example heart rate, blood volume pulse, cortisol levels in sweat which may correspond to stress levels, or any other signal that corresponds to a patient's heart rate or to a change in stress levels) or otherwise patient biopotential information 42 in an augmented manner on a target site or on a stereoscopic video of
15 the target site such that the biopotential information 42 appears to be superimposed on the target site. An example system measuring cortisol levels in sweat is described in the publication by Onur Parlak et al., entitled "Molecularly selective nanoporous membrane-based wearable organic electrochemical device for noninvasive cortisol sensing" Science Advances 20 Jul 2018:Vol. 4, no. 7, pp1-10, which is incorporated
20 by reference herein in its entirety, as if set forth fully herein.

The target site may include a patient 14, as the patient 14 is seated in a treatment chair 24 (e.g. dental treatment chair), a treatment site 14a on the patient 14 or on any suitable real world environment in a clinician's office, through augmented reality as
25 discussed hereinafter. Alternatively the patient biopotential information may be displayed directly on a screen of a smart glass worn by the clinician without being superimposed in an augmented fashion. The patient biopotential information 42 may be analyzed to detect changes in a patient's stress level or discomfort, for example as compared to corresponding baseline data.

30

The display device 12 may be connected to or form part of a computer system 100. The computer system 100 (also shown in FIG. 3) may include a tracking system 2 and a processor 122. The tracking system 2 may alternatively be separate from the computer system and may form at least part of any of the devices, components, and/or
35 systems discussed herein. The tracking system 2 may be electrically connected to a processor 122 and may offer real-time location data for a precise location and orientation of images and objects in a common coordinate system. In an exemplary

embodiment herein, the tracking system may be sensor based e.g. as a biopotential sensor system **26** to track the patient's biopotential information **42**. To measure the heart rate of a patient **14** (or a signal that may correspond to the patient's heart rate or stress/discomfort levels), the biopotential sensor system **26** may include a biopotential sensor interface (not shown) which may include a biopotential sensor or measurement device such as, for example, the electrode sensors **38** of FIG. 2, cortisol measuring sensor (not shown) or any other suitable device that provides a signal that is the patient's heart rate or corresponds to the patient's heart rate or stress level. The measuring device may also be configured to measure Electrodermal Activity (EDA) and Heart Rate variability (HRV) wherein a predetermined signal processing method may be used to extract significant features from the physiological signals in order to predict a type of stress of the patient thereby differentiating between serious stress (such as stress related to pain during dental treatment) related and non-serious stress (such as stress that is unrelated to pain during dental treatment). Significant features such as mean or magnitude of Skin Conductance Level (SCL) and Skin Conductance Response (SCR), features that may give a general idea of Heart rate activity and the spread of the values etc. may be selected to discriminate between serious stress and non-serious stress as disclosed in the Publication "Profiling visual and verbal stress responses using electrodermal heart rate and hormonal measures", by Pawel et al, which is herein incorporated by reference in its entirety, as if set forth fully herein.

The measurement device may alternatively be a handheld device (not shown) through which the patient **14** may manually register pain sensations or stress level through, for example, clicking on a button on said handheld device. In an embodiment in which the biopotential sensor/measurement device is an electrode sensor **38**, the electrode sensor may be mounted on a handle **40** of the treatment chair **24**. The biopotential sensor interface (not shown) may be in communication with the tracking system **2** and/or computer system **100**, the processor **122** of which may process output signals from the biopotential sensor system **26**. The biopotential sensor interface may read (e.g., retrieve or receive) electrical signals corresponding to the biopotential signals generated by the user and may then send the signals to the tracking system **2** and/or computer system **100**.

5 The tracking system may also be vision based, for example as cameras for visual tracking of the patient **14**, features of the patient (such as the head or buccal cavity), and/or predetermined markers (not shown) placed on the patient **14**. Said visual tracking may be achieved using, for example object/pattern recognition. A camera system **3** such as a 3D optical tracking system and/or stereoscopic camera system may
10 be included in the computer system and/or may form or be a part of the tracking system **2**. The camera system **3** may also be embedded in the display device **12** of the clinician **10**. The camera system may operate under one of several depth sensing principles including, for example, (i) structural light, (ii) Time of Flight (ToF) and/or (iii) stereoscopic principles explained hereinafter. For cameras employing structural
15 light, a light source may be used to project a known pattern onto the patient **14**, and a receiver may detect the distortion of the reflected pattern to calculate depth map based on geometry. For cameras employing Time of Flight (ToF) principles, a light source may send out a pulse, and a sensor may detect a reflection of the pulse from the patient **14** in order to record its time of flight. Knowing that and the constant speed of
20 light, the system may calculate how far away the patient **14** is. Alternatively, a modulated light source may be sent, and a phase change of light reflected from the patient may be detected. For cameras employing stereoscopic principles, multiple cameras may be placed at different positions to capture multiple images of the patient, and a depth map may be calculated based on geometry. This depth information may
25 be used to track the patient's location during treatment (e.g. during dental treatment).

In yet another embodiment, the tracking system may be a fusion of sensor based and vision based tracking system. A wireless protocol may be used to transmit known marker locations for tracking.

30

The processor **122** may be configured to receive real time patient biopotential data, to analyze said data and to display said analyzed data to the clinician **10** in an augmented manner by (i) overlaying the analyzed data in the real world environment through, for example, a display device **12** such as a see-through Augmented Reality Glasses/ HUD
35 display or (ii) overlaying the analyzed data on a stereoscopic video of the patient using e.g. a head mounted stereoscopic display. Alternatively, the analyzed data may

- 5 be displayed in a non-augmented manner, such as on a smart watch (not shown) or as an optical or audible output on an output device such as a monitor.

In so doing, the clinician **10** may receive real-time patient biopotential information **42** and may respond to the changing information by, for example, stopping a treatment
10 activity, slowing down a treatment activity, refreshing anesthesia, etc. in order to improve the patient experience without losing focus of the treatment in order to “check in” with the patient.

In an exemplary embodiment of the present invention, the patient biopotential
15 information **42** may optionally be overlaid on a treatment site **14a** after a request is received from the clinician **10** through a user interface **126** of the computer system **100** (such as a gesture recognition system and/or a voice recognition system or the like) before or during drilling treatment procedure. Overlaying of the patient biopotential data **42** and/or analysis of the patient biopotential data, including, for
20 example, a treatment regimen **52**, on the patient **14** or treatment site **14a** through the display **12** may be performed dynamically and in real time and may be achieved by the processor **122** working in tandem with the tracking system **2** wherein changes in position of (i) the patient **14** and/or (ii) the clinician **10**, captured by the tracking system **2**, may be translated into corresponding changes in positions of the overlaid
25 patient biopotential data **42** such that said patient biopotential data **42** routed to a screen of the display device **12** appear directly superimposed on target regions/sites **14a** (e.g. buccal cavity) of the patient **14** even as the patient **14** and/or or clinician **10** moves. Moreover, responsive to a request from the clinician **10** the processor may be configured to provide the ongoing or predetermined suggestions of alterations to a
30 planned treatment procedure based on measured patient discomfort.

Computer System for Visualizing Patient Stress

Having described a system **1** for facilitating the communication of patient stress using
35 augmented reality reference will now be made to FIG. **3**, which shows a block diagram of a computer system **100** that may be employed in accordance with at least some of the example embodiments herein. Although various embodiments may be

5 described herein in terms of this exemplary computer system **100**, after reading this description, it may become apparent to a person skilled in the relevant art(s) how to implement the disclosure using other computer systems and/or architectures.

In one example embodiment herein, the computer system **100** may include at least one
10 computer processor **122** and may include a tracking system **2**, user interface **126** and input unit **130**. The input unit **130** may be used by the clinician **10** along with a display unit **128** such as a monitor to send information to the computer processor **122**. In one exemplary embodiment herein, the input unit **130** is a finger or stylus to be used on a touchscreen interface (not shown). The input unit **130** may alternatively be a
15 gesture/voice recognition device, a trackball, a mouse or other input device such as a keyboard or stylus. In one example, the display unit **128**, the input unit **130**, and the computer processor **122** may collectively form the user interface **126**.

The computer processor **122** may include, for example, a central processing unit (“CPU”), a multiple processing unit, an application-specific integrated circuit
20 (“ASIC”), a field programmable gate array (“FPGA”), or the like. The processor **122** may be connected to a communication infrastructure **124** (e.g., a communications bus, or a network). In an embodiment herein, the processor **122** may receive a request for patient biopotential information **42** and may obtain instructions concerning the request from one or more storage units of the computer system **100**. The processor **122** may
25 then load said instructions and execute the loaded instructions such as routing the patient biopotential data **42** to a screen of the display device **12** such that the patient biopotential data **42** is overlaid on the treatment site **14a** such that said patient biopotential data **42** appears directly superimposed on said treatment site **14a**. In yet another alternative embodiment of the present invention, the computer system may
30 use projection based augmented reality systems wherein, for example, a projector and depth sensors, along with the tracking system **2** and/or markers on the patient **14** (e.g. hidden markers) may project the patient biopotential data **42** directly onto target sites **14a** (e.g. buccal cavity) of the patient. Herein, a display **12** such as augmented reality glasses may not be needed.

35

One or more steps/procedures for visually communicating patient stress/discomfort may be stored on a non-transitory storage device in the form of computer-readable

5 program instructions. To execute a procedure, the processor **122** loads the appropriate instructions, as stored on a storage device, into memory and then executes the loaded instructions as shown in FIG. **4** discussed hereinafter.

10 The computer system **100** may further comprise a main memory **132**, which may be a random access memory ("RAM") and also may include a secondary memory **134**.

15 The secondary memory **134** may include, for example, a hard disk drive **136** and/or a removable-storage drive **138** (e.g., a floppy disk drive, a magnetic tape drive, an optical disk drive, a flash memory drive, and the like). The removable-storage drive **138** may read from and/or write to a removable storage unit **140** in a well-known manner. The removable storage unit **140** may be, for example, a floppy disk, a magnetic tape, an optical disk, a flash memory device, and the like, which may be written to and read from by the removable-storage drive **138**. The removable storage unit **140** may include a non-transitory computer-readable storage medium storing computer-executable software instructions and/or data.

20 In further alternative embodiments, the secondary memory **134** may include other computer-readable media storing computer-executable programs or other instructions to be loaded into the computer system **100**. Such devices may include a removable storage unit **144** and an interface **142** (e.g., a program cartridge and a cartridge interface); a removable memory chip (e.g., an erasable programmable read-only memory ("EPROM") or a programmable read-only memory ("PROM")) and an associated memory socket; and other removable storage units **144** and interfaces **142** that allow software and data to be transferred from the removable storage unit **144** to other parts of the computer system **100**.

30 The computer system **100** also may include a communications interface **146** that enables software and data to be transferred between the computer system **100** and external devices. Such an interface may include a modem, a network interface (e.g., an Ethernet card or an IEEE 802.11 wireless LAN interface), a communications port (e.g., a Universal Serial Bus ("USB") port or a FireWire® port), a Personal Computer Memory Card International Association ("PCMCIA") interface, Bluetooth®, and the like. Software and data transferred via the communications interface **146** may be in

5 the form of signals, which may be electronic, electromagnetic, optical or another type of signal that may be capable of being transmitted and/or received by the communications interface **146**. Signals may be provided to the communications interface **146** via a communications path **148** (e.g., a channel). The communications path **148** may carry signals and may be implemented using wire or cable, fiber optics,
10 a telephone line, a cellular link, a radio-frequency (“RF”) link, or the like. The communications interface **146** may be used to transfer software or data or other information between the computer system **100** and a remote server or cloud-based storage (not shown).

15 One or more computer programs or computer control logic may be stored in the main memory **132** and/or the secondary memory **134**. The computer programs may also be received via the communications interface **146**. The computer programs may include computer-executable instructions which, when executed by the computer processor **122**, cause the computer system **100** to perform the methods as described hereinafter.

20 In another embodiment, the software may be stored in a non-transitory computer-readable storage medium and loaded into the main memory **132** and/or the secondary memory **134** of the computer system **100** using the removable-storage drive **138**, the hard disk drive **136**, and/or the communications interface **146**. Control logic
25 (software), when executed by the processor **122**, causes the computer system **100**, and more generally the system for augmented reality visualization, to perform all or some of the methods described herein.

Implementation of other hardware arrangement so as to perform the functions
30 described herein will be apparent to persons skilled in the relevant art(s) in view of this description.

Method for Visualizing Patient Stress.

35 Having described the computer system **100** of FIG. **3**, methods for Visualizing Patient Stress will now be further described in conjunction with FIG. **4** which show steps for

- 5 acquiring patient biopotential information **42** via sensors and displaying them on smart devices to improve the treatment and the patient experience.

FIG. **4** shows a process **200** for visualizing patient stress. The process may start when a patient **14** engages a biopotential sensor system **26** (such as one including an
10 electrode sensor **38** which may be attached to a handle of a treatment chair **24**) in Step **S100**. Patient biopotential information **42** may be requested or received in Step **S200** from the electrode sensor **38**. Upon receipt of the patient biopotential information **42**, which may initially be in a raw format such as an analog format, the data may be converted into a readable format such as a digital format. The data may then be
15 analyzed in Step **S300**. Said analysis may involve obtaining baseline biopotential information corresponding to the patient's stress/discomfort level before dental treatment begins. Said information may then be routed to a screen of the display unit **12** such that the information appears directly superimposed on the patient **14** or a treatment site **14a** in an augmented manner (Step **S400**). Using data from the tracking
20 system **2** including, for example, (i) real time data tracking changes in patient biopotential information **44** (ii) real time data tracking clinician movements **46**, and/or (iii) real time data tracking patient movements **50**, the augmented data routed to the display device **12** may be dynamically updated in real time for overlay on the patient **14** or treatment site **14a** or otherwise any other predetermined real world site in a field
25 of view of the clinician **10** such that said augmentation appears directly superimposed on said site. Said predetermined site may be recognized using, for example, object recognition on data obtained from the camera system **3**.

In an exemplary embodiment of the present invention, the augmentation, at least
30 including patient biopotential information **42** may be constantly updated. Alternately, the augmentation may be updated intermittently, for example, when the patient biopotential information **42** exceeds a predetermined value. In a further exemplary embodiment of the present invention, retrieval of the patient biopotential information **42** from the biopotential sensor system **26** may be terminated for a duration of time
35 and said retrieval may thereafter be resumed upon a request from the clinician **10** to do so.

5 Moreover, instructions such as (i) predetermined instructions or suggestions for proceeding with dental treatment based on recorded changes in stress or discomfort levels and/or (ii) instructions based on artificial intelligence may be displayed automatically for the clinician **10** or upon a request such as a request from the clinician **10** through the input unit **130**. More specifically, in Step **S500**, artificial
10 intelligence data analysis may be used on images of the patient **14** taken by the camera system **3** and/or on a database of patient biopotential information **42** to generate a set instructions for the processor **122** to accurately or substantially accurately detect patient pain, stress or discomfort. The processor **122** may be adapted to execute one or more algorithms, such as artificial intelligence and/or other
15 algorithms, which may include being adapted to execute algorithms based on one or more inputs, such as inputs derived from or otherwise based on ongoing patient treatments, past patient treatments, corresponding recorded stress levels, the results of patient treatments or otherwise treatment information. The processor **122** may be adapted to recommend or otherwise identify one or more treatment regimens **52** for
20 one or more detected stress levels and display said treatment regimens **52** to the clinician **10**. In an exemplary embodiment of the present invention, the treatment regimen **52** may include, for example, refreshing anesthesia, stopping a treatment activity, slowing down a treatment activity etc., in order to improve patient experience. Systems for employing artificial intelligence in treatment planning, such
25 as are described in US Patent No. **9788917B2**, entitled “Methods and systems for employing artificial intelligence in automated orthodontic diagnosis and treatment planning” which is hereby incorporated by reference herein in its entirety, as if set forth fully herein, may be used.

30 In yet another embodiment, the computer system **100** may be in communication with a tool **16** (e.g. dental drill) being used by the clinician **10** on the patient **14**. Based on recorded patient biopotential data **42** exceeding a preferably predetermined threshold value, the computer system may obtain control of the tool **16** and may deactivate the tool **16** or reduce power sent to said tool **16**.

35

Moreover, treatment regimens **52** may be provided to the clinician on the display device **12** in one or more forms including (a). visual form wherein for example red-

- 5 yellow-green lights, colored lights or otherwise lights indicate real time stress/discomfort levels of the patient **10** (b). auditory form wherein for example verbal queues or other audible sounds may be activated indicating real time stress/discomfort levels of the patient, and/or (c) haptic form wherein for example an intensity of vibration of vibrating element (not shown) increases or decreases as
10 recorded stress levels approach a predetermined value.

In view of the foregoing description, it may be appreciated that the example embodiments described herein provide a method, system and computer readable storage media for visualizing patient stress/discomfort levels.

15

- Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar to or equivalent to those described herein may be used in the practice or testing of the disclosure, suitable
20 methods and materials are described above. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety to the extent allowed by applicable law and regulations. The disclosure may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it may therefore be desired that the present embodiment be
25 considered in all respects as illustrative and not restrictive. Any headings utilized within the description are for convenience only and have no legal or limiting effect.

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CLAIMS

1. A system utilizing augmented visualization, the system comprising: a display device for augmented visualization, a biopotential sensor system adapted to retrieve patient biopotential information; and at least one processor configured to
10 obtain said patient biopotential information from the biopotential sensor;
 analyze said patient biopotential information to obtain a treatment regimen; and
 overlay the patient biopotential information and/or the treatment regimen as an augmentation on a predetermined site through a display device for augmented visualization such that the patient biopotential information appears directly
15 superimposed on said predetermined site,
 wherein the biopotential sensor system comprises a handheld device through which the patient manually registers his or her pain sensations and/or stress levels.
2. The system according to claim 1, wherein said at least one processor is further
20 configured to analyze the patient biopotential information to obtain a change in the patient biopotential information by comparing a first biopotential data corresponding to the patient's stress/discomfort level at a first time period to a biopotential data corresponding to the patient's stress/discomfort level at a second time period.
- 25 3. The system according to claim 2, wherein the first time period is a time period selected before treatment begins and the second time period is a time period selected after treatment begins.
- 30 4. The system according to any one of claims 1 to 3, wherein said at least one processor is further configured to provide the treatment regimen based on said change in the patient biopotential information.
- 35 5. The system according to any one of claims 1 to 4, wherein said predetermined site is a site selected from the group consisting of the patient, a region of the patient, or site in a field of view of a user of the display device.

- 5 6. The system according to any one of claim 1 to 5, wherein said patient biopotential information is obtained in real-time.
7. The system according to any one of claims 1 to 6, wherein said patient biopotential information includes information selected from the group consisting of heart rate,
10 blood volume pulse, cortisol levels in sweat, blood pressure, breathing frequency, body temperature, a signal that corresponds to the patient's heart rate and a signal that corresponds to a stress level of the patient
8. The system according to any one of claims 1 to 7, wherein said at least one
15 processor is further configured to update the augmentation based on data selected from the group consisting of (i) real time data tracking changes in patient biopotential information (ii) real time data tracking clinician movements and (iii) real time data tracking patient movements.
- 20 9. The system according to any one of claims 1 to 8, further comprising a tracking system configured to offer real-time position data for a precise location, orientation and update of patient biopotential data and/or treatment regimen in a common coordinate system, wherein the tracking system is sensor based and/or vision based.
- 25 10. The system according to any one of claims 1 to 9, wherein the biopotential sensor system includes an electrode sensor, a cortisol measuring sensor, a blood pressure sensor, a breathing frequency sensor, a body temperature sensor and/or a sensor that provides a signal that is the patient's heart rate or corresponds to the patient's heart rate or stress level.

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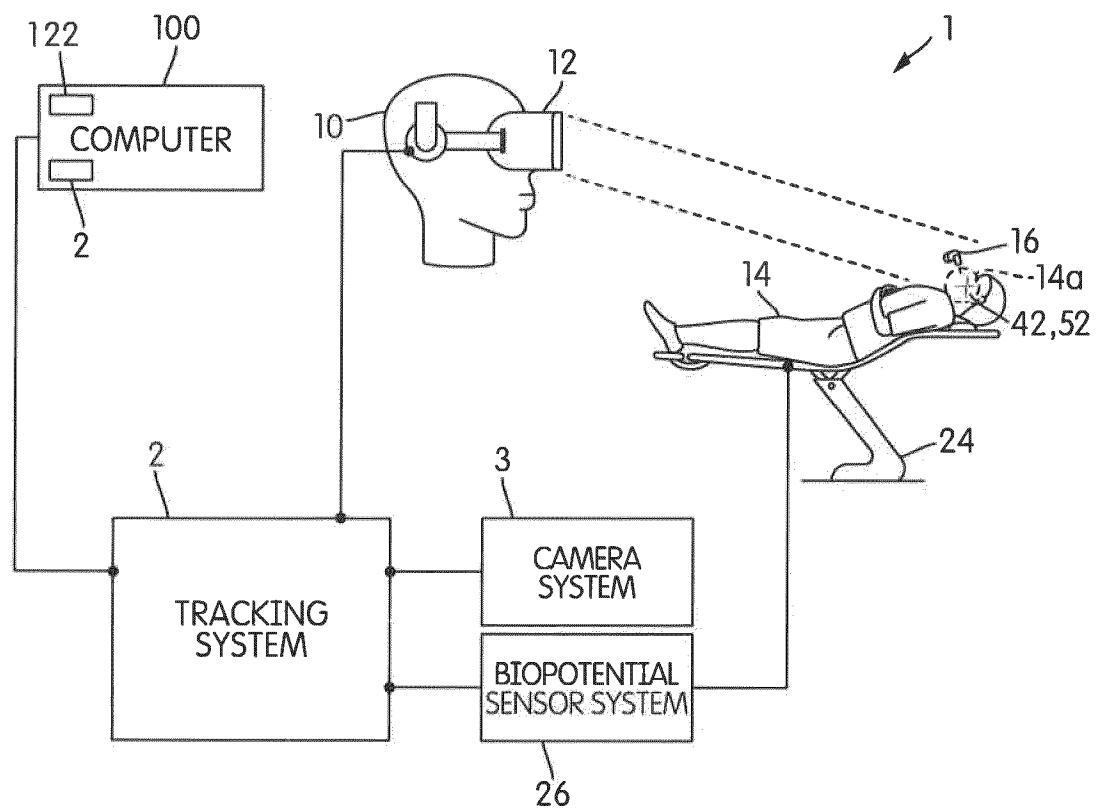


FIG. 1

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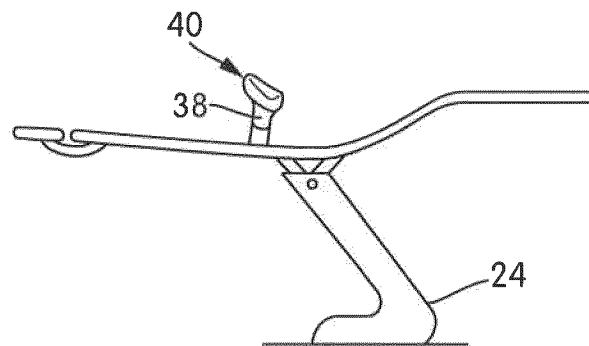


FIG. 2

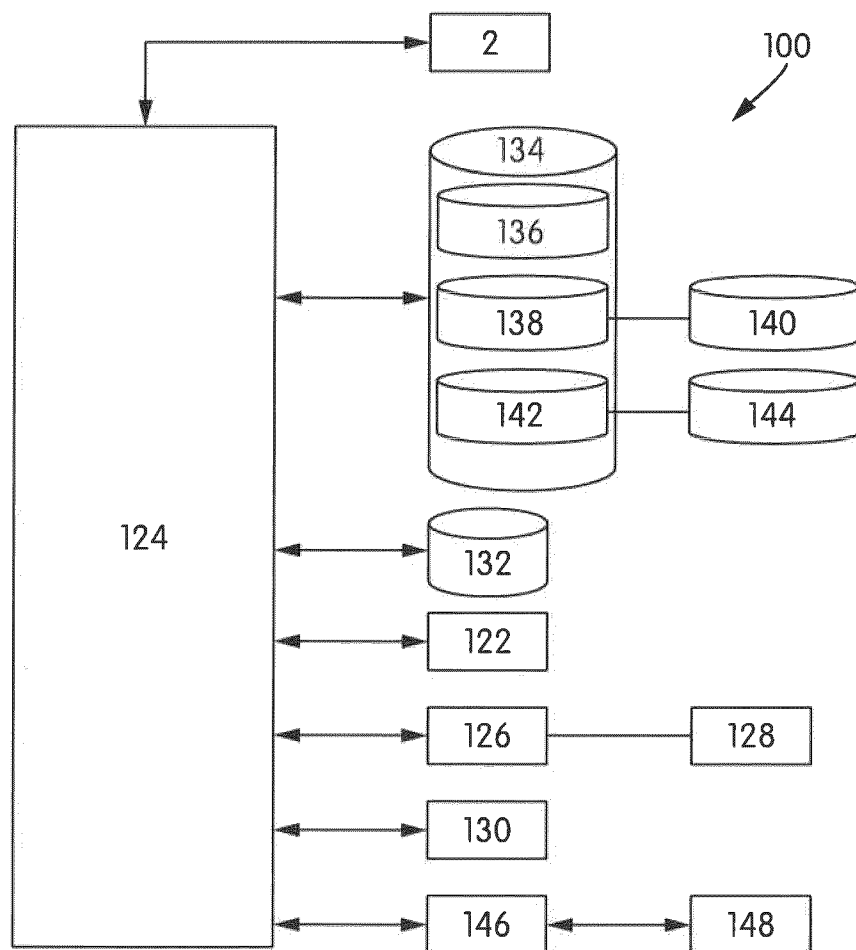


FIG. 3

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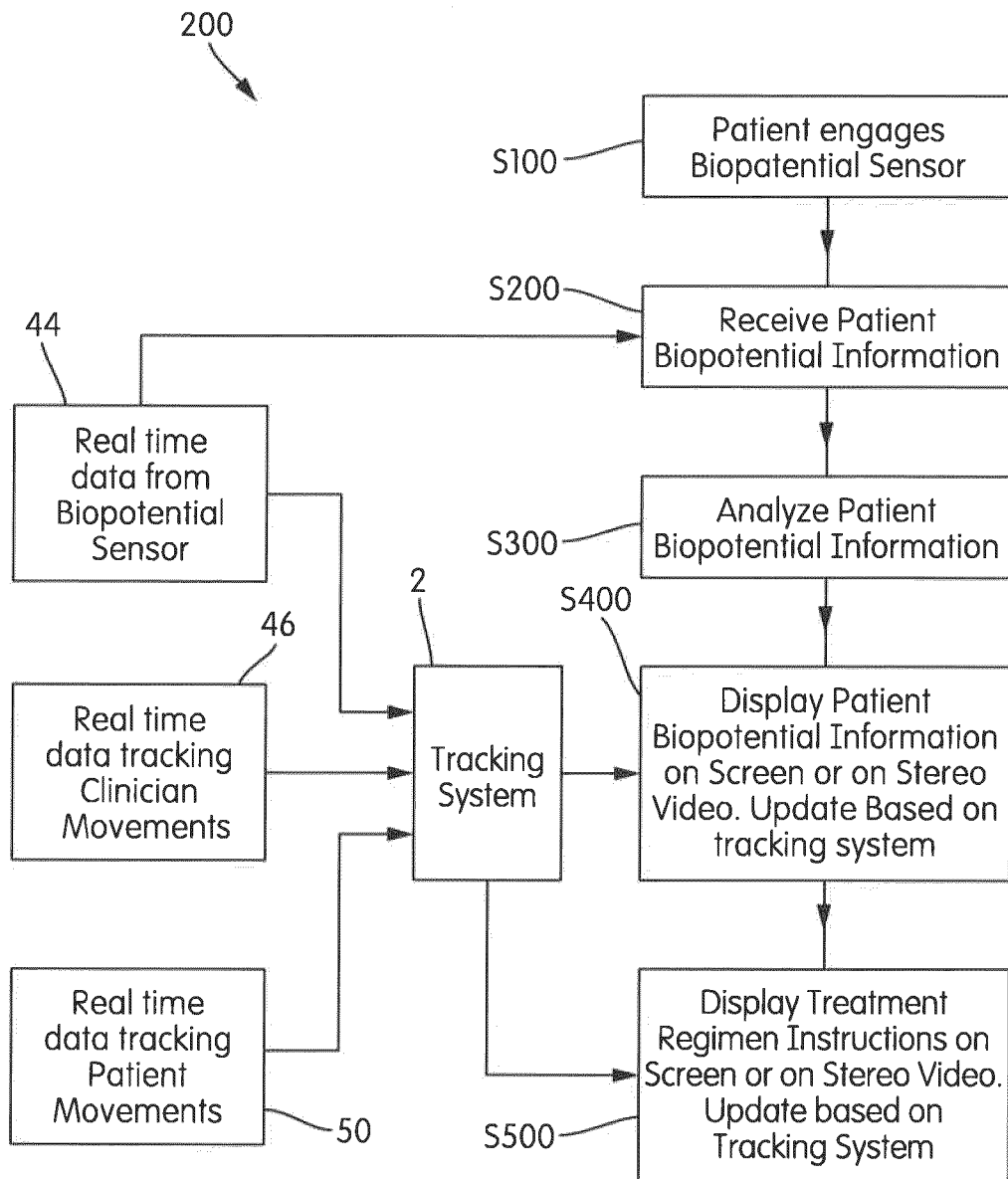


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/051879

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	A61B5/00	A61B5/021 A61B5/024 A61B5/04 A61B5/08
ADD.	A61B5/145	
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
A61B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/151778 A1 (ARIS MD INC [US]) 8 September 2017 (2017-09-08) paragraphs [0107], [0121], [0128], [0145] - [0188], [0250], [0381], [0389], [0396]; figure 9	1-10
A	US 2018/082480 A1 (WHITE JOHN R [US] ET AL) 22 March 2018 (2018-03-22) paragraphs [0019], [0064], [0083]; figure 11A	1-10
A	US 2018/032130 A1 (MEGLAN DWIGHT [US]) 1 February 2018 (2018-02-01) paragraphs [0005], [0008], [0017], [0036]; figures 1,5	1-10
	-/--	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
17 March 2020		25/03/2020
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Chau, Thoi Dai

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/069120 A1 (BENNER THOMAS [DE] ET AL) 9 March 2017 (2017-03-09) paragraphs [0009], [0010], [0018], [0038]; figure 4 -----	1-10
A	US 2018/033261 A1 (MAYERS JARED A [US]) 1 February 2018 (2018-02-01) paragraphs [0002], [0006] -----	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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