US 20160310066A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2016/0310066 A1**

Wiedenhoefer et al. (43) **Pub. Date: Oct. 27, 2016**

(54) **JOINT SENSOR SYSTEM AND METHOD OF OPERATION THEREOF**

(71) Applicant: **Consensus Orthopedics, Inc.**, El Dorado Hills, CA (US)

(72) Inventors: **Curt Wiedenhoefer**, Davis, CA (US); **Justin Anthony Creel**, Fair Oaks, CA (US); **Brian James Katerberg**, Folsom, CA (US); **Joshua Dale Howard**, Sacramento, CA (US)

(21) Appl. No.: **15/077,793**

(22) Filed: **Mar. 22, 2016**

Related U.S. Application Data

(60) Provisional application No. 62/136,925, filed on Mar. 23, 2015, provisional application No. 62/136,892, filed on Mar. 23, 2015.

Publication Classification

(51) **Int. Cl.**

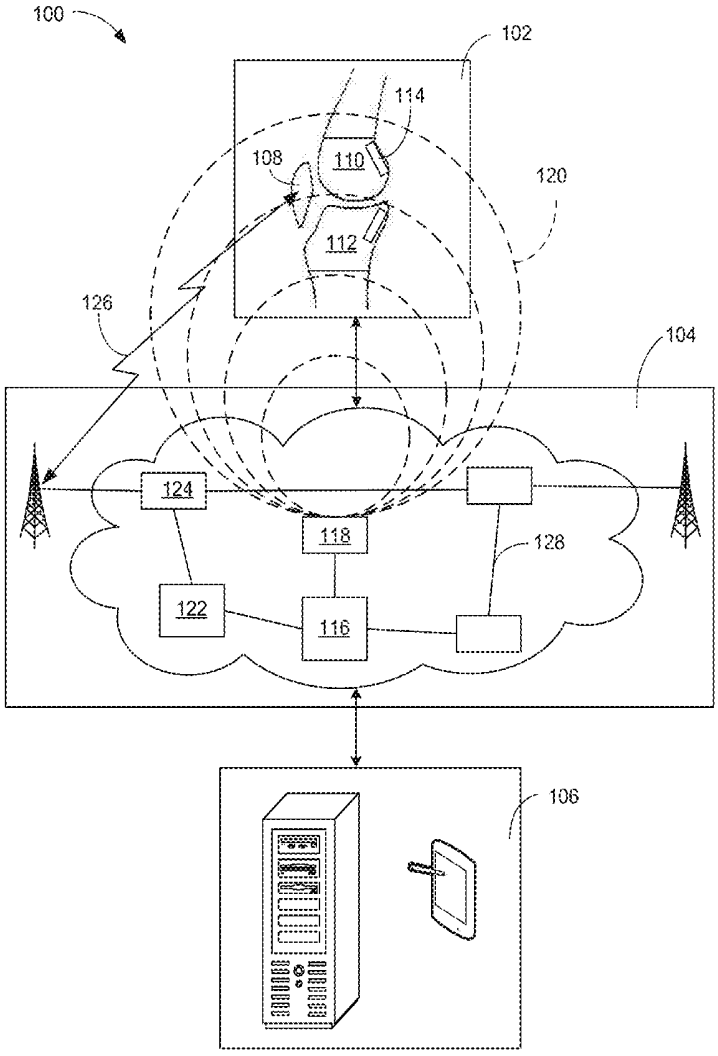
A61B 5/00	(2006.01)
A61B 5/11	(2006.01)
A61B 5/01	(2006.01)

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

CPC ***A61B 5/4585*** (2013.01); ***A61B 5/0086*** (2013.01); ***A61B 5/0013*** (2013.01); ***A61B 5/0035*** (2013.01); ***A61B 5/01*** (2013.01); ***A61B 5/0031*** (2013.01); ***A61B 5/6878*** (2013.01); ***A61B 5/112*** (2013.01); ***A61B 5/1121*** (2013.01); *A61B 2090/309* (2016.02)

(57) **ABSTRACT**

A joint sensor system includes: an implantable joint camera assembly; an optional data communication device coupled to the joint camera assembly; a data processing device for collecting joint data; and a display coupled to the data processing device for monitoring the joint interface using the joint camera assembly.



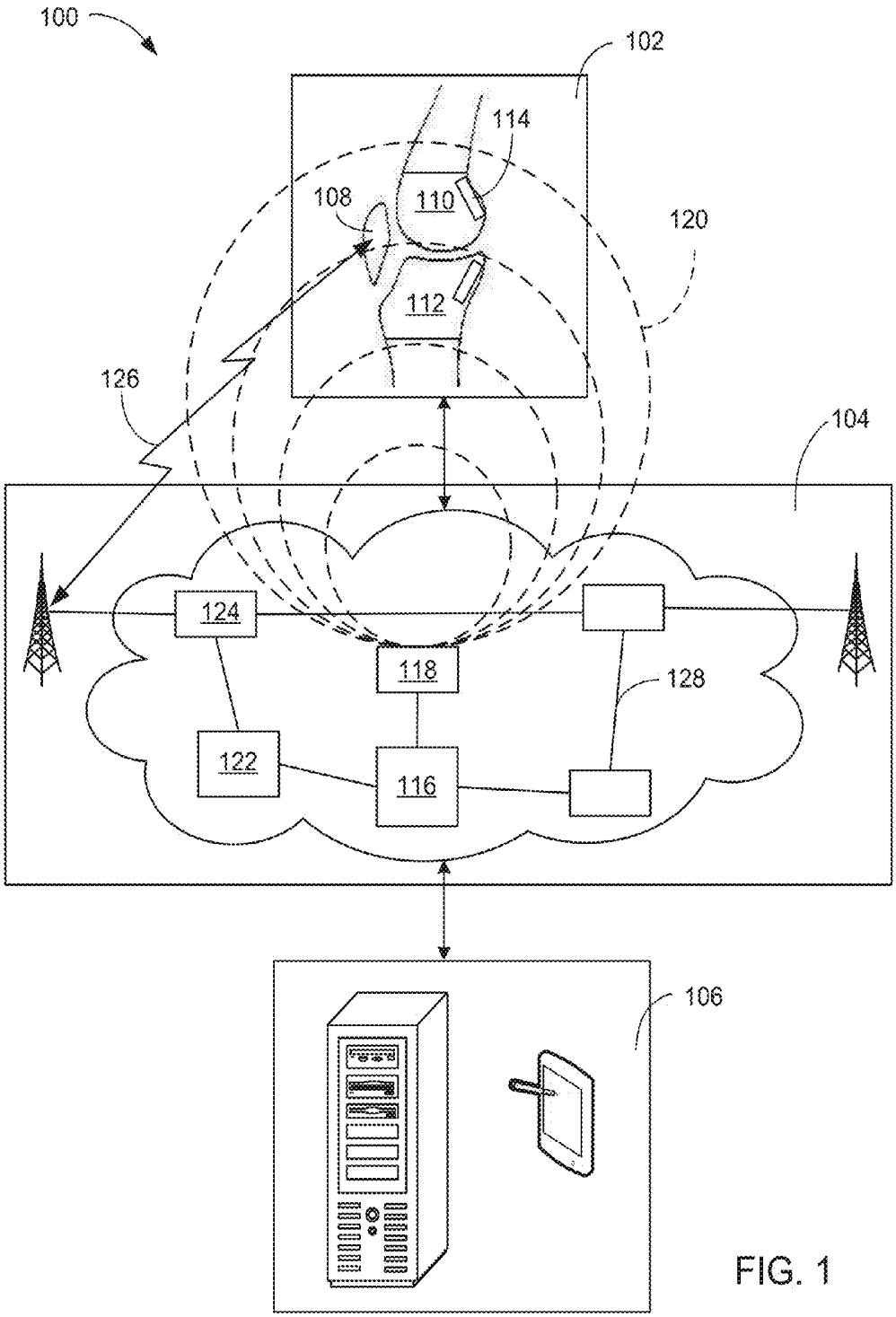


FIG. 1

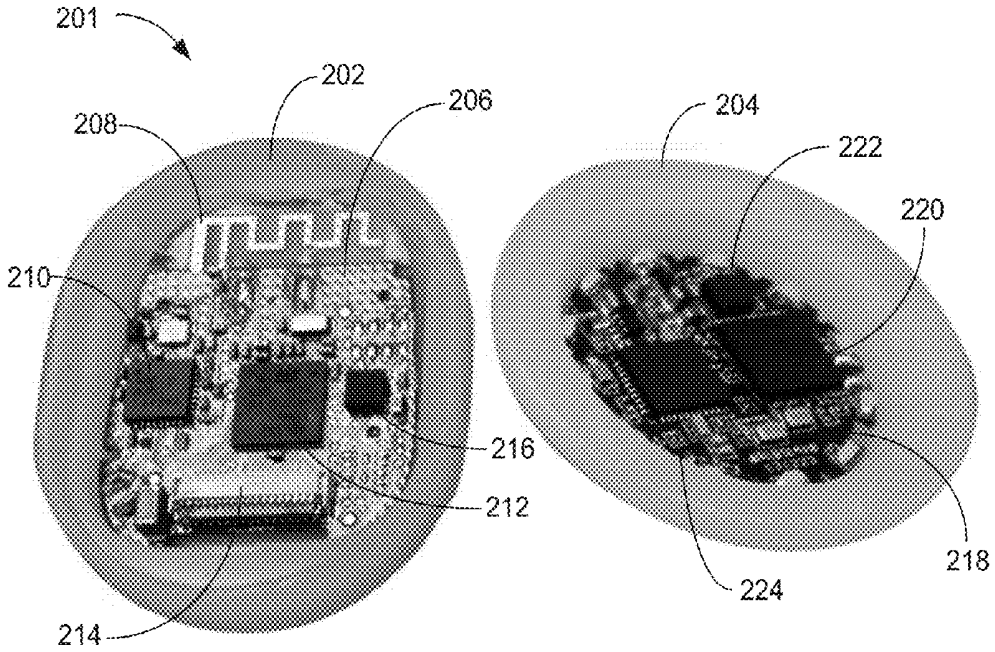

201
202
206
208
204
222
220
210
216
212
218
224
214

FIG. 2

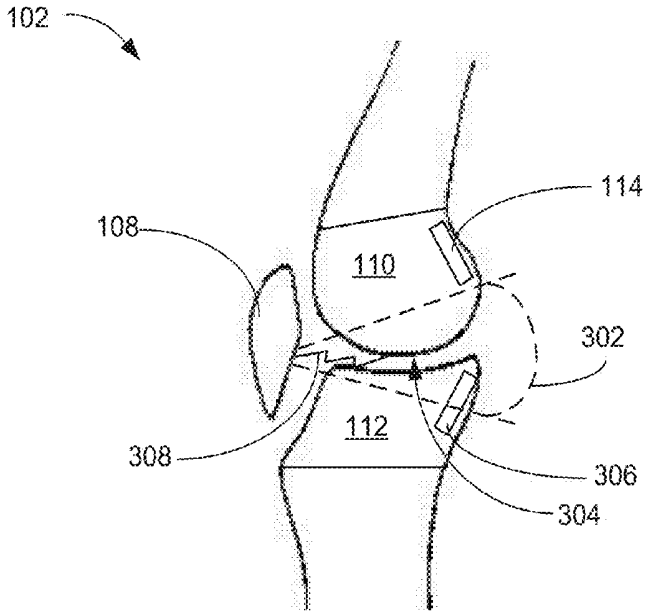

102
114
108
110
302
112
308
306
304

FIG. 3

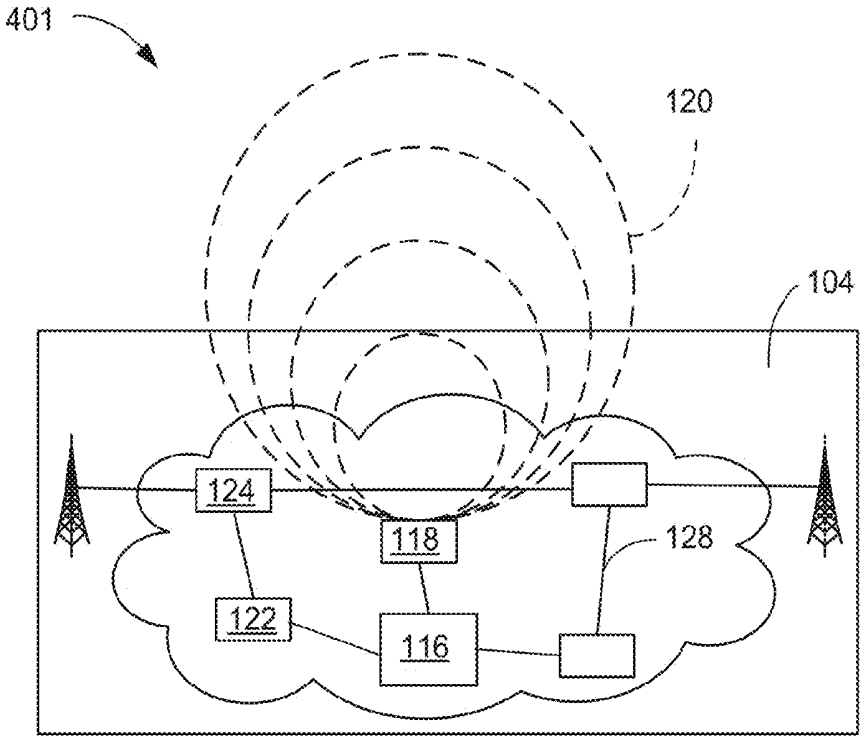


FIG. 4

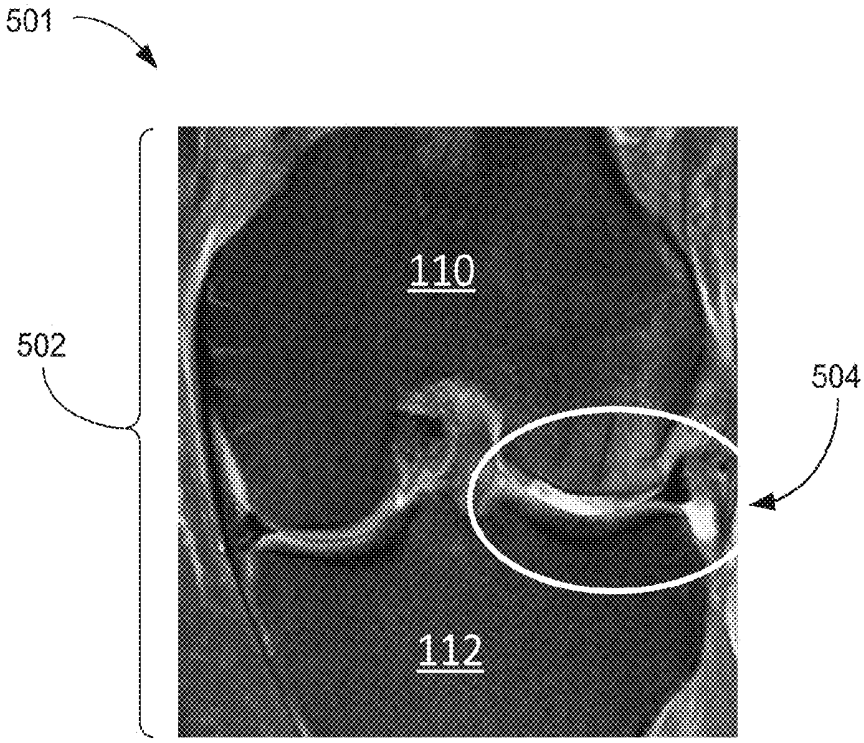


FIG. 5

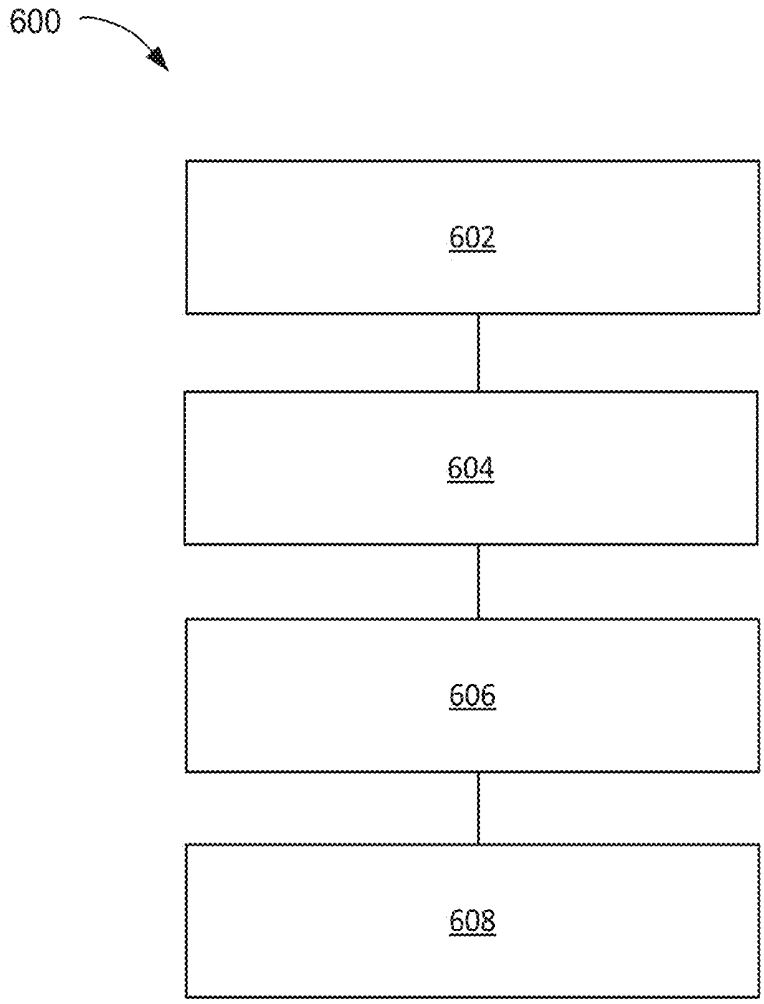


FIG. 6

JOINT SENSOR SYSTEM AND METHOD OF OPERATION THEREOF

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/136,925 filed Mar. 23, 2015, and the subject matter thereof is incorporated herein by reference thereto.

TECHNICAL FIELD

[0002] An embodiment of the present invention relates generally to an implant system, and more particularly to a system for a surgical implant of joints.

BACKGROUND

[0003] Modern medicine has provided new processes that can help patients with bone and joint maladies get back their freedom of movement and reducing or eliminating the pain that they experience. In situations where the patient has worn-out or damaged a joint, it is possible to replace the joint with a structure that can merge with the skeletal structure and restore pain free movement and function. The surgical implants do involve some risks. Despite the benefits that implants provide, there are occasional issues which arise which if treated efficiently can lead to expedited recovery. Unfortunately, invasive methods are often used to acquire information to guide the surgeon's decision, resulting in additional recovery and pain. If non-invasive tools were available for this same data collection, there would be improvements to the patient and health care system.

[0004] Thus, a need still remains for a joint sensor system to help administer, rehabilitate, and monitor a patient with the implant inside the body. In view of the ever-increasing commercial competitive pressures, along with growing consumer expectations and the diminishing opportunities for meaningful product differentiation in the marketplace, it is increasingly critical that answers be found to these problems. Additionally, the need to reduce costs, improve efficiencies and performance, and meet competitive pressures adds an even greater urgency to the critical necessity for finding answers to these problems.

[0005] Solutions to these problems have been long sought but prior developments have not taught or suggested any solutions and, thus, solutions to these problems have long eluded those skilled in the art.

SUMMARY

[0006] One embodiment is a joint sensor system including an implantable joint camera assembly for implantation proximate a joint structure of a patient; a data processing device coupled to the joint camera assembly to collect joint data from the joint camera assembly; and a display coupled to the data processing device to monitor the joint interface using the joint camera assembly.

[0007] In at least some embodiments, the system further includes a data communication device to be disposed external to the patient and to communicate with the joint camera assembly and the data processing device. In at least some embodiments, the joint camera assembly includes a power source and the data communication device includes a wireless power generator to couple to and charge the power source. In at least some embodiments, the joint camera assembly includes an illumination controller to direct illumination on a portion of the joint structure. In at least some embodiments, the joint camera assembly further includes an illumination element to produce at least one of white light, ultraviolet light, or infrared light. In at least some embodiments, the illumination controller and illumination element facilitate identification of a foreign material in the joint structure.

[0008] In at least some embodiments, the joint camera assembly includes an ultrasound controller configured to monitor the joint structure. In at least some embodiments, the joint camera assembly includes a camera configured and arranged to produce a video or still image of the joint structure. In at least some embodiments, the joint camera assembly includes at least one sensor to produce sensor data for determination of at least one of a temperature, a pressure, a range of motion, a step count, or shock to the joint structure. In at least some embodiments, the joint camera assembly is configured and arranged for surgical implantation proximate an upper implant assembly, a lower implant assembly, or a natural joint.

[0009] Another embodiment is an implantable joint camera assembly for implantation near a joint structure. The joint camera assembly includes a camera to produce at least one of a still picture or video of the joint structure; a controller assembly coupled to the camera to transmit data from the camera to an external device; and an illumination arrangement to produce and control at least one of white light, ultraviolet light, or infrared light to facilitate operation of the camera.

[0010] In at least some embodiments, the joint camera assembly further includes a power source. In at least some embodiments, the power source is configured and arranged to be charged using an external wireless power generator. In at least some embodiments, the illumination arrangement includes an illumination controller to direct illumination on a portion of the joint structure. In at least some embodiments, the illumination arrangement further includes an illumination element to produce at least one of white light, ultraviolet light, or infrared light. In at least some embodiments, the illumination arrangement facilitates identification of a foreign material in the joint structure.

[0011] In at least some embodiments, the joint camera assembly further includes an ultrasound controller configured to monitor the joint interface. In at least some embodiments, the joint camera assembly further includes at least one sensor configured and arranged to produce sensor data for determination of at least one of a temperature, a pressure, a range of motion, a step count, or shock to the joint structure. In at least some embodiments, at least one of the at least one sensor is an accelerometer, temperature sensor, ultrasound sensor, motion detector, shock sensor, magnetometer, gyroscope, proximity sensor, infrared sensor, thermistor, piezoelectric sensor, or sonar sensor. In at least some embodiments, the joint camera assembly is configured and arranged for surgical implantation proximate an upper implant assembly, a lower implant assembly, or a natural joint.

[0012] Certain embodiments of the invention have other steps or elements in addition to or in place of those mentioned above. The steps or elements will become apparent to those skilled in the art from a reading of the following detailed description when taken with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a functional block diagram of an example embodiment of a joint sensor system.

[0014] FIG. **2** is a functional diagram of an example embodiment of a joint sensor camera and controller assembly.

[0015] FIG. **3** is a functional diagram of an example embodiment of the joint sensor implant of FIG. **1**.

[0016] FIG. **4** is a functional diagram of an example embodiment of the data communication device.

[0017] FIG. **5** is an example image of a joint interface of the joint sensor system.

[0018] FIG. **6** is a flow chart of a method of operation of a joint sensor system in a further embodiment of the present invention.

DETAILED DESCRIPTION

[0019] The following embodiments are described in sufficient detail to enable those skilled in the art to make and use the invention. It is to be understood that other embodiments would be evident based on the present disclosure, and that system, process, or mechanical changes may be made without departing from the scope of an embodiment of the present invention.

[0020] In the following description, numerous specific details are given to provide a thorough understanding of the invention. However, it will be apparent that the invention may be practiced without these specific details. In order to avoid obscuring an embodiment of the present invention, some well-known circuits, system configurations, and process steps are not disclosed in detail.

[0021] The drawings showing embodiments of the system are semi-diagrammatic, and not to scale and, particularly, some of the dimensions are for the clarity of presentation and are shown exaggerated in the drawing figures. Similarly, although the views in the drawings for ease of description generally show similar orientations, this depiction in the figures is arbitrary for the most part. Generally, the embodiments can be operated in any orientation. The embodiments have been numbered first embodiment, second embodiment, etc. as a matter of descriptive convenience and are not intended to have any other significance or provide limitations for an embodiment of the present invention.

[0022] The term "image" referred to herein can include a two-dimensional image, three-dimensional image, video frame, a computer file representation, an image from a camera, a video frame, or a combination thereof. For example, the image can be a machine readable digital file, a physical photograph, a digital photograph, a motion picture frame, a video frame, an x-ray image, a scanned image, or a combination thereof.

[0023] The term "module" referred to herein can include software, hardware, or a combination thereof in an embodiment of the present invention in accordance with the context in which the term is used. For example, the software can be machine code, firmware, embedded code, application software, or a combination thereof Also for example, the hardware can be circuitry, processor, computer, integrated circuit, integrated circuit cores, a pressure sensor, an inertial sensor, a microelectromechanical system (MEMS), passive devices, or a combination thereof. Further, if a module is written in the apparatus claims section below, the modules are deemed to include hardware circuitry for the purposes and the scope of apparatus claims.

[0024] The term "unit" referred to herein is a circuit formed of hardware components or hardware state machines used for specific functions. The "unit" can be for timing critical functions, is self-contained, and does not necessarily include software functions or support.

[0025] The term "proximate" referred to herein means in direct contact with or providing as small a separation as possible. By way of an example, a cast is proximate to a fractured bone because it is formed directly on the flesh that covers the fractured bone.

[0026] Referring now to FIG. **1**, therein is shown an example embodiment of a joint sensor system **100**. The example embodiment of a joint sensor system **100** includes a joint sensor implant **102** connected to a data processing device **106** by a data communication device **104**, which is a support structure or fixture that can provide power to the joint sensor implant **102** as well as retrieving the data captured by the joint sensor implant **102**. The data communication device **104** can be coupled to the data processing device **106** through a wireless or wired network. In other embodiments, instead of using a data communication device **104** as an intermediary, the joint sensor implant **102** can be coupled to the data processing device **106** directly using wireless or wired communications. U.S. patent application Ser. No. _____, entitled "Systems and Methods for Monitoring an Orthopedic Implant and Rehabilitation", filed on even date herewith (Attorney Docket No. CONO-1-001.1), incorporated herein by reference in its entirety, includes other systems and methods of monitoring a joint with a joint camera assembly, as described herein, and provides examples of other sensors that can be utilized in the joint sensor system **100**, joint sensor implant, **102**, and data communication device **104**, as well as elements and user interfaces that may be part of the data processing device **106** (and referred therein as a user device or clinician device.

[0027] The joint sensor implant **102** can be a joint replacement structure having a monitoring and observation function. The joint sensor implant **102** can include a joint camera assembly **108** that is proximate an upper implant assembly **110** and a lower implant assembly **112**. Both the upper implant assembly **110** and the lower implant assembly **112** can include embedded sensors **114** that can be configured to monitor temperature, acceleration, location, pressure, and shock.

[0028] The joint camera assembly **108** can act as a communication hub for the joint sensor implant **102** allowing the transfer of sensor data between the embedded sensors **114** and the joint camera assembly **108**. The joint camera assembly **108** can include the functions of one or more of a communication controller, data storage, inductive power converter, a camera, accelerometer, temperature sensor, light source, ultrasound, motion detector, shock sensor, magnetometer, gyroscope, proximity sensor, infrared sensor, thermistor, piezoelectric sensor, or sonar sensor.

[0029] The joint camera assembly **108** can provide a visual record of the action of the upper implant assembly **110** and the lower implant assembly **112**. The visual record can detect changes (for example, movement, wear, or damage) in the physical interface between the upper implant assembly **110** and the lower implant assembly **112**, which can be essential in the monitoring of the condition and health of the recipient of the joint sensor implant **102**. The joint camera

assembly can also be used, for example, to monitor one or more of the following: wear on the implant, wear on surrounding bone or other tissue, particulates in body fluids, white blood cells or infection, joint surfaces, soft tissue impingements, bone healing, cement to bone interface integrity, implant adhesion/loosening, placement of needles into joint, implant alignment and articulation; biological joint repair such as that initiated by stem cell injection; biological ingrowth into implant; or the like or any combination thereof.

[0030] The visual record can include, for example, video, a still image, dimensional measurements, a surface map, fluid color, fluid opacity, presence of foreign materials or particles, or the like or any combination thereof. For purposes of illustration, the present description uses video as an example, but it will be understood that any other type of visual record including, but not limited, to those listed previously can be used alternatively or additionally.

[0031] In at least some embodiments, the joint camera assembly can utilize landmarks/markers (line-of-sight or embedded) on the joint (implant or natural) for assessment of position, especially for relative position of parts of the joint. Visual landmarks or implanted non-visible IR arrays can be used to identify, for example, accurate position of joint camera assembly with respect to the components of the joint, identify accurate flexion angle of the joint (not just assumed flexion provided by the joint camera assembly onboard accelerometer), measure if there is varus/valgus tilt; or the like or any combination thereof. It will be understood that the joint sensor implant **102** may utilize image intensification methods, such as those used for night vision devices, or illumination with near infrared or other infrared or visible light or utilize infrared sensors for thermal imaging.

[0032] The data communication device **104** can include a power source **116**, which can be an alternating current (AC) power source or a direct current (DC) power source depending on the application of the data communication device **104**. In an embodiment the power source **116** can be a battery for portable applications or an AC converter for a tethered fixture. The power source **116** can be coupled to an inductive power generator **118**. The inductive power generator **118** can generate an electro-magnetic field **120** that can be coupled to the joint sensor implant **102** in order to provide primary power or to change internal batteries in the joint camera assembly **108** and the embedded sensors **114**. Other wireless power generators can be used in place of the inductive power generator such as, for example, a wireless power generator that utilizes ultrasound or WiFi or other rf power signals to generate power in the power source **116**.

[0033] External sensors **122** can be incorporated in the data communication device **104** for monitoring the position and movement of the data communication device **104** relative to the joint sensor implant **102** and movements of the joint sensor implant **102** itself. The external sensors **122** can be coupled to a communication controller **124**, which can manage the transfer of joint data **126** between the data communication device **104** and the joint sensor implant **102** as well as the communication between the data communication device **104** and the data processing device **106**. The communication controller **124** can include a wireless transmission mechanism, such as RFID, BlueTooth® Low Power, ZigBee®, Nearby®, WiFi, cellular, or the like.

[0034] The external sensors **122** are a configurable hardware module that can detect one or more of location, pressure, temperature, noise, and proximity, as well as operating peripheral devices, security interactions, and communication functions. The external sensors **122** can provide additional environmental detection in support of the joint sensor implant **102**. The external sensors can detect temperature, identify movement type, detect a pulse, measure G-force impact, identify acceleration, and issue alerts based on established thresholds.

[0035] It is understood that the data communication device **104** can be in the form of a phone, WiFi router, joint support brace, clothing, or it can be fitted into a piece of furniture in order to be proximate the joint sensor implant **102**. The furniture can be, for example, a bed mattress, an examination table, a wheel chair, an ottoman, exercise apparatus, or an office chair.

[0036] The data communication device **104** can receive the joint data **126** as video data and other telemetry from the joint sensor implant **102**, through the communication controller **124**, and transfer the joint data **126** to the data processing device **106**. In at least some embodiments, the data processing device **106** must be authorized to communicate with the data communication device **104**. The authorization can be in the form of an encryption key exchange, key word exchange, or an encryption exchange with a predetermined key.

[0037] The data communication device **104** can have a wired interconnection **128** between the power source **116**, the inductive power generator **118** (or other wireless power generator), the external sensors **122**, the communication controller **124**, or a combination thereof. The wired interconnection **128** can be used for distribution of primary power as well as the exchange of external sensor data between the external sensors **122** and the communication controller **124**.

[0038] The communication controller **124** can verify the authorization of the data processing device **106** prior to transferring the joint data **126** and the external sensor data to the data processing device **106**. The data processing device **106** can format the joint data **126** and the external sensor data for display to a user. The data processing device **106** can be a particularized machine, such as a server, a portable computing device, a thin client, a notebook, a netbook, a smartphone, a tablet computer, a personal digital assistant, or a cellular phone, and as specific examples, an Apple iPhone™, Android™ smartphone, or Windows™ platform smartphone.

[0039] The communication controller **124** can be coupled to the data processing device **106** by a wireless or wired interface depending on the application implementation. The data processing device **106** can allow direct viewing of the joint data **126** including the video from the joint camera assembly **108** and data collected by the embedded sensors **114**. The data processing device **106** can instruct the joint camera assembly **108** to apply a digital zoom of certain areas of the interface between the upper implant assembly **110** and the lower implant assembly **112**. The data processing device **106** can instruct the joint camera assembly **108** can instruct the joint camera assembly **108** to switch operational modes between visible light, infrared light, ultraviolet light, or ultrasound. The different modes of the joint camera assembly **108** can provide assistance with or otherwise facilitate identification of foreign matter in the interface between the upper implant assembly **110** and the lower implant assembly **112**. The foreign material can include bone, cement chips,

metallic particles, or a combination thereof. The joint camera assembly **108** can identify wear patterns in the upper implant assembly **110** and the lower implant assembly **112**.

[0040] It is understood that the joint sensor implant **102** can be implemented for any joint targeted within the body and can include but is not limited to shoulder, hip, knee, ankle, fingers, and wrist. The number, type, and position of the embedded sensors **114** and the joint camera assembly **108** are an example only and the implemented number and position may differ.

[0041] The joint sensor implant **102** can assist in the rehabilitation of the patient that has been injured or subject to a surgical process. The data, measurements, or readings from the sensors of the joint sensor implant **102** can be used to determine, measure, calculate, or otherwise observe one or more types of information, such as, for example, GPS location, step count, pulse profile and recovery time, joint shock monitor, sleep profile, resting duration and calories burned. The addition of the external sensors **122** can provide additional environmental and physical information for the joint sensor system **100**. As such the joint sensor system **100** can have applications in performance monitoring, conditioning programs, surgical rehabilitation, or to address chronic disorders. By monitoring a history of the pulse and temperature in the joint data **126**, a conditioning recovery time can be calculated as an indicator of the condition of the subject being monitored.

[0042] It is understood that the joint used in the description is a knee joint, but this is an example only and other joints can be monitored by the joint sensor system **100**. An embodiment of the joint sensor system **100** can include the data communication device **104** implemented directly within the joint camera assembly housing (implant), directly within the communication controller (phone), or in a third component, such as in a sock, shirt, shorts, glove, or some other garment or brace that can be configured to position the external sensor **122** proximate the target joint, implant, or bone structure. In other embodiments, the joint sensor implant **102** can directly communicate with the data processing device **106**.

[0043] Referring now to FIG. **2**, therein is shown a functional diagram of an example embodiment of a joint sensor camera assembly **201**. The functional diagram of the example embodiment of the joint sensor camera assembly **201** depicts a controller assembly **202** and a camera assembly **204** separated from each other. The controller assembly **202** is formed to be the outside of the joint camera assembly **108** of FIG. **1**. The camera assembly **204** is formed to be the inner interface of the joint camera assembly **108** and is positioned adjacent to the interface between the upper implant assembly **110** of FIG. **1** and the lower implant assembly **112** of FIG. **1**.

[0044] The controller assembly **202** can include controller circuit carrier **206** that can support a communication antenna **208**, a configurable sensor **210**, a communication controller **212**, a memory storage device **214**, and power controller **216**. The controller circuit carrier **206** can be a printed circuit board, a flex circuit, an epoxy filled lead carrier, or the like.

[0045] The controller assembly **202** can manage the communication between the joint camera assembly **108** and the data communication device **104** of FIG. **1**, as well as controlling the functions of the camera assembly **204**. The configurable sensor is a configurable hardware module that can detect location, pressure, temperature, noise, and proximity, as well as operating peripheral devices, security interactions, and communication functions. The configurable sensor **210** can be directly connected to the communication controller **212** through the controller circuit carrier **206**. The communication controller **212** can be directly coupled to the memory storage device **214** for collecting the joint data **126** of FIG. **1** during the operation of the joint camera assembly **108**.

[0046] The power controller **216** can utilize a portion of the controller circuit carrier **206** for harvesting the electromagnetic field **120** of FIG. **1**. The power controller **216** can provide the primary power for the operations of both the controller assembly **202** and the camera assembly **204**. The power controller **216** can also charge a battery (not shown) for basic operation of the joint camera assembly **108** when not in the range of the data communication device **104**.

[0047] The camera assembly **204** can include a camera circuit carrier **218** that can couple a camera controller **220**, an illumination controller **222**, and an ultrasound controller **224**. The camera circuit carrier **218** can be a printed circuit board, a flex circuit, an epoxy filled lead carrier, or the like.

[0048] The camera controller **220** can operate a pixel array (not shown) on the underside of the camera circuit carrier **218**. The camera controller **220** can operatively change the function of the pixel array and the illumination controller **222** in order to change the function of the camera between visible light, infrared light, or ultraviolet light. Each of these selections can detect and help identify, for example, any foreign material that might enter the interface between the upper implant assembly **110** and the lower implant assembly **112**, or help improve the evaluation of the surfaces of the joint. The camera controller can also turn-off the pixel array and the illumination controller **222** in order to activate the ultrasound controller **224**. The ultrasound controller **224** can generate an output frequency and map the returned frequencies in order to identify any debris that might be in the field of view of the joint camera assembly or to provide further analysis of the motion of the components of joint **108**. It will be recognized that instead of an ultrasound controller, another high frequency generator, such as a WiFi or Bluetooth controller, can be used in, for example, a Doppler observation device.

[0049] It has been discovered that an embodiment of the joint camera assembly **108**, including the controller assembly **202** and the camera assembly **204**, can monitor and display the internal interface between the upper implant assembly **110** and the lower implant assembly **112**. The early detection of debris or foreign matter in the interface between the upper implant assembly **110** and the lower implant assembly **112** can allow knowledgeable corrective action to be performed. The ability of the joint camera assembly **108** to utilize different spectra of light can identify the type of material detected in the interface between the upper implant assembly **110** and the lower implant assembly **112** without the need of any surgical analysis. This ability can allow minor corrections to be applied before a major joint replacement surgery is required.

[0050] It is understood that different modules or combinations of modules can be implemented in the controller assembly **202** and the camera assembly **204**. The addition of different modules or controllers in the joint camera assembly **108** can enable additional analysis and corrective processes.

[0051] By way of an example, the joint sensor implant **102** can include the joint camera assembly **108** as part of a

patella implant of an artificial knee. For this example, the joint sensor implant **102** can be configured to count steps or monitor actions experienced by the joint sensor implant **102**. This aspect can provide feedback on the effects of physical therapy on the joint sensor implant **102**.

[0052] The joint sensor implant **102** can be further configured to monitor a temperature or a temperature trend with the joint sensor implant **102** as a whole, or areas physically in contact with or adjacent to the joint sensor implant **102**. The monitoring of temperature around the joint sensor implant **102** can be a precursor to an infection and can provide feedback necessary to support the healing process. Another precursor to infection can be change in pressure or a pressure trend detected by the joint sensor implant **102**.

[0053] The joint sensor implant **102** can be further configured to monitor particles in the interface between the upper implant assembly **110** and the lower implant assembly **112**. The joint camera assembly **108** can detect particles or density of particles in the area of the joint sensor implant **102**. By manipulating the illumination controller **222**, the joint camera assembly can identify the type of material that is detected as particles. The joint camera assembly can switch-off the illumination controller **222** and utilize the ultrasound controller **224** can detect particles that might not be visible in the available light spectra. This aspect can provide needed insight to addressing damage of infection around the joint sensor implant **102**.

[0054] The joint sensor implant **102** can be further configured to monitor a range of motion of the joint sensor implant **102**. This can be useful in the physical therapy of the recipient of the joint sensor implant **102** and provide goal feedback by marking range of motion thresholds as well as warnings for exceeding range of motion limits.

[0055] It has been discovered that the joint sensor system **100** can enable frequent monitoring of the health and flexibility of the joint sensor implant **102** without requiring office visits to an administering surgeon. The ability to monitor temperature, pressure, range of motion, step activity, wear of the upper implant assembly **110** and the lower implant assembly **112**, and analyze any particles can promote rapid healing and enable quick response to potential infections and damage.

[0056] Referring now to FIG. **3**, therein is shown a functional diagram of an example embodiment of the joint sensor implant **102** of FIG. **1**. The functional diagram of an example embodiment of the joint sensor implant **102** depicts the joint camera assembly **108** positioned adjacent to the upper implant assembly **110** and the lower implant assembly **112**. The joint camera assembly **108** can be surgically implanted and positioned to provide a view angle **302** across a joint interface **304** between the upper implant assembly **110** and the lower implant assembly **112**. The joint interface **304** can include contact areas and gaps between the upper implant assembly **110** and the lower implant assembly **112**.

[0057] The capabilities of the joint camera assembly **108** can be complemented by the addition of the embedded sensors **114** can provide additional analysis of the conditioning and general health of the patient having the joint sensor implant **102**. A configurable sensor **306** can be in communication with the joint camera assembly **108** and can be reconfigured to provide specific feedback as required for analysis of the joint sensor implant **102**. The joint camera assembly **108** can control the illumination controller **222** to project a spectrum of light **308** across the viewing angle **302**. The illumination controller **222** can be configured to project the spectrum of light **308** as white light, ultra-violet light, infrared light, or other spectra to provide analysis of the joint interface **304**.

[0058] In an alternative embodiment, the joint camera assembly **108** can be surgically implanted to replace a portion of the patella of a natural knee joint that has undergone ligament or tendon surgery. The joint camera assembly **108** can monitor the rehabilitation of the natural knee joint and provide video feedback without further invasive surgery to the knee.

[0059] The joint camera assembly **108** can provide the view angle **302** across the ligaments of the natural knee joint, as well as monitoring temperature, pressure, range of motion, step activity, and warnings associated with falls, twists, or potential damage to the natural knee joint. The joint camera assembly **108** can operate in conjunction with the data communication device **104** and the data processing device **106** to aid in rehabilitation and analysis of the healing after the surgical process. After the patient has healed, the joint camera assembly **108** can remain idle and inactive unless needed for check-ups or further analysis.

[0060] The view angle **302** within the geographic lens position can be design as fixed or adjustable. A lens "array" could be provided and selected through a MEMS actuated mirror (not shown) for change viewing angle, focus, macro vs. micro, etc. Use of a wide angle (fish-eye) lens can further enhance the view angle **302**.

[0061] The camera controller **220** of FIG. **2** can control the MEMS actuated mirror to shift the view angle **302**. The housing for the camera assembly **204** can be in a hermetically sealed enclosure in which at least a portion is translucent thus allowing light (visible, IR, ultraviolet) to pass.

[0062] Multiple lens and light source capabilities or polarizations can be provided and selected by the camera controller **220** through the MEMS actuated mirror to direct light leaving the light source, or returning to the camera/sensor. As other examples, an Infra-Red filter can provide thermal analysis to help detect hot spots indicating things such as infection or high friction.

[0063] The joint sensor implant **102** and the joint camera assembly **108** can provide a post-surgical video and statistical analysis of the recovery of the patient. The analytic capabilities of the joint camera assembly **108** can have application in the joint replacement operations as well as reconstruction of the natural knee joint. The utilization of the data communication device **104** can provide monitoring and configuration capabilities that can allow the joint camera assembly **108** to become a rehabilitation and general health monitoring system.

[0064] Referring now to FIG. **4**, therein is shown a functional diagram of an example embodiment of the data communication device **104**. The functional diagram of the example embodiment of the data communication device **104** depicts the power source **116**, which can be an alternating current (AC) power source or a direct current (DC) power source depending on the application of the data communication device **104**. In an embodiment the power source **116** can be a battery for portable applications or an AC converter for a tethered fixture. The power source **116** can be coupled to the inductive power generator **118**. The inductive power generator **118** can generate an electro-magnetic field **120** that can be coupled to the joint sensor implant **102** of FIG. **1** in order to provide primary power or to change internal

batteries in the joint camera assembly **108** of FIG. **1** and the embedded sensors **114** of FIG. **1**.

[0065] The external sensors **122** can be incorporated in the data communication device **104** for monitoring the position and movement of the data communication device **104** relative to the joint sensor implant **102** and movements of the joint sensor implant **102** itself. The external sensors **222** can be reconfigurable to monitor different aspects of the joint camera assembly **108** of FIG. **1**. The data communication device **104** can be a stand-alone apparatus that can be configured to only monitor the external sensors **222**. The data communication device **104** can be used without the joint sensor implant **102** and can be self-inclusive or integrated in a piece of clothing, a support brace, a wearable device, or the like.

[0066] The external sensors **122** can be configured to provide sensor data, such as GPS location, step count, pulse profile and recovery time, joint shock monitor, sleep profile, resting duration and calories burned. The configuration of the external sensors **122** can be modified by receiving a configuration command from the data processing device **106** of FIG. **1**. The external sensors **122** can be coupled to a communication controller **124**, which can manage the transfer of joint data **126** of FIG. **1** between the data communication device **104** and the joint camera assembly **108** as well as the communication between the data communication device **104** and the data processing device **106**. The communication controller **124** can be configured to provide a storage capability that will allow collecting periodic data for analysis and delivery to the data processing device **106**. The communication controller **124** can include a wireless transmission mechanism, such as RFID, BlueTooth® Low Power, ZigBee®, Nearby®, WiFi, cellular, or the like.

[0067] The external sensors **122** are a configurable hardware module that can detect location, pressure, temperature, noise, and proximity, as well as operating peripheral devices, security interactions, and communication functions. The external sensors **122** can provide additional environmental detection in support of the joint sensor implant **102**. The external sensors **122** can detect temperature, identify movement type, detect a pulse, measure G-force impact, identify acceleration, and issue alerts based on established thresholds.

[0068] It is understood that the data communication device **104** can be in the form of a joint support, brace, clothing, or it can be fitted into a piece of furniture in order to be proximate the joint sensor implant **102**. The furniture can be, for example, an examination table, a wheel chair, an ottoman, exercise apparatus, or an office chair. When the data communication device **104** is incorporated in a tethered application, such as furniture, the joint camera assembly **108** can provide the body data **126**, including video data, and environmental data, such as temperature, pressure, pulse, acoustic data, particle analysis, or foreign material identification.

[0069] It has been discovered that the data communication device **104** can support the joint camera assembly **108** whether it is installed over the natural knee joint or the joint sensor implant **102**. The data communication device **104** can be used in a stand-alone application to monitor physical activity, such as exercise, physical therapy, conditioning regimens, or the like.

[0070] Referring now to FIG. **5**, therein is shown an example image of a joint interface **501** of the joint sensor system **102** of FIG. **1**. The example image of the joint interface **501** provided by the joint camera assembly **108** of FIG. **1** proximate a joint structure **502** depicts the upper implant assembly **110** and the lower implant assembly **112**. A highlighted region can depict a foreign material **504** between the upper implant assembly **110** and the lower implant assembly **112**. The joint camera assembly **108** can be configured to change the spectra of the illumination controller **222** in an attempt to identify the material content of the foreign material **504** in the joint interface **501**.

[0071] The configuration changes can be controlled through the data processing device **106** of FIG. **1**. The joint data **126** can be viewed on the data processing device **106** as the configuration is changed. Under control of a technician or a surgeon the foreign material **504** can be identified and a course of corrective action determined. In some cases, the ultrasound controller **224** can generate sufficient vibration energy that the foreign material **504** can be broken-up and dispersed without surgical processes.

[0072] The joint camera assembly **108** can be positioned proximate the joint structure **502** to view the joint interface **501** of the upper implant assembly **110** and the lower implant assembly **112** or a natural knee joint **502** to monitor the health and performance of the joint interface **501**. It is understood that the joint structure **502** can be the natural knee joint **502** of a patient that has undergone ligament or tendon surgery. The application of the joint camera assembly **108** can monitor the healing process of the natural knee joint **502** by allowing a video inspection of the joint interface **501** without the need of further surgical intervention.

[0073] It has been discovered that the joint sensor system **102** and the joint camera assembly **108** can provide advanced monitoring, analysis, and corrective action without additional invasive surgery. The ability to view the joint interface **501** and determine the make-up of the foreign material **504** can allow a less invasive corrective action to be applied to remove the foreign material **504**.

[0074] It is understood that the example of the joint interface **501** shown is a knee joint, but the joint structure **502** can be any jointed area of the body. It is further understood that the joint camera assembly **108** can be formed in an appropriate shape to support the monitoring of the targeted joint structure **502**. By way of an example, the joint interface **501** of the natural knee joint **502** can include the area joining the femur to the tibia in the human structure.

[0075] Referring now to FIG. **6**, therein is shown a flow chart of a method **600** of operation of a joint sensor system **100** in a further embodiment of the present invention. The method **600** includes: positioning a joint camera assembly proximate a joint structure in a block **602**; coupling a data communication device to the joint camera assembly in a block **604**; accessing a data processing device coupled to the data communication device for collecting joint data in a block **606**; and displaying a joint interface, on the data processing device, for monitoring the joint interface with the joint camera assembly in a block **608**.

[0076] The resulting method, process, apparatus, device, product, and/or system is straightforward, cost-effective, uncomplicated, highly versatile, accurate, sensitive, and effective, and can be implemented by adapting known components for ready, efficient, and economical manufacturing, application, and utilization. Another important aspect of an embodiment of the present invention is that it valuably

supports and services the historical trend of reducing costs, simplifying systems, and increasing performance.

[0077] These and other valuable aspects of an embodiment of the present invention consequently further the state of the technology to at least the next level.

[0078] While the invention has been described in conjunction with a specific best mode, it is to be understood that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations that fall within the scope of the included claims. All matters set forth herein or shown in the accompanying drawings are to be interpreted in an illustrative and non-limiting sense.

What is claimed is:

1. A joint sensor system, comprising:

an implantable joint camera assembly configured and arranged for implantation proximate a joint structure of a patient;

a data processing device coupled to the joint camera assembly and configured and arranged to collect joint data from the joint camera assembly; and

a display coupled to the data processing device configured and arranged to monitor the joint interface using the joint camera assembly.

2. The system of claim **1**, further comprising a data communication device configured and arranged to be disposed external to the patient and to communicate with the joint camera assembly and the data processing device.

3. The system of claim **2**, wherein the joint camera assembly comprises a power source and the data communication device comprises a wireless power generator configured and arranged to couple to and charge the power source.

4. The system of claim **1**, wherein the joint camera assembly comprises an illumination controller configured and arranged to direct illumination on a portion of the joint structure.

5. The system of claim **4**, wherein the joint camera assembly further comprises an illumination element configured and arranged to produce at least one of white light, ultraviolet light, or infrared light.

6. The system of claim **5**, wherein the illumination controller and illumination element are configured and arranged to facilitate identification of a foreign material in the joint structure.

7. The system of claim **1**, wherein the joint camera assembly comprises an ultrasound controller configured to monitor the joint structure.

8. The system of claim **1**, wherein the joint camera assembly comprises a camera configured and arranged to produce a video or still image of the joint structure.

9. The system of claim **1**, wherein the joint camera assembly comprises at least one sensor configured and arranged to produce sensor data for determination of at least one of a temperature, a pressure, a range of motion, a step count, or shock to the joint structure.

10. The system of claim **1**, wherein the joint camera assembly is configured and arranged for surgical implantation proximate an upper implant assembly, a lower implant assembly, or a natural joint.

11. An implantable joint camera assembly configured and arranged for implantation near a joint structure, comprising:

a camera configured and arranged to produce at least one of a still picture or video of the joint structure;

a controller assembly coupled to the camera and configured and arranged to transmit data from the camera to an external device; and

an illumination arrangement configured and arranged to produce and control at least one of white light, ultraviolet light, or infrared light to facilitate operation of the camera.

12. The joint camera assembly of claim **11**, further comprising a power source

13. The joint camera assembly of claim **12**, wherein the power source is configured and arranged to be charged using an external wireless power generator.

14. The joint camera assembly of claim **11**, wherein the illumination arrangement comprises an illumination controller configured and arranged to direct illumination on a portion of the joint structure.

15. The joint camera assembly of claim **11**, wherein the illumination arrangement further comprises an illumination element configured and arranged to produce at least one of white light, ultraviolet light, or infrared light.

16. The joint camera assembly of claim **11**, wherein the illumination arrangement is configured and arranged to facilitate identification of a foreign material in the joint structure.

17. The joint camera assembly of claim **11**, further comprising an ultrasound controller configured to monitor the joint interface.

18. The joint camera assembly of claim **11**, further comprising at least one sensor configured and arranged to produce sensor data for determination of at least one of a temperature, a pressure, a range of motion, a step count, or shock to the joint structure.

19. The joint camera assembly of claim **18**, wherein at least one of the at least one sensor is an accelerometer, temperature sensor, ultrasound sensor, motion detector, shock sensor, magnetometer, gyroscope, proximity sensor, infrared sensor, thermistor, piezoelectric sensor, or sonar sensor.

20. The joint camera assembly of claim **11**, wherein the joint camera assembly is configured and arranged for surgical implantation proximate an upper implant assembly, a lower implant assembly, or a natural joint.

* * * * *

专利名称(译)	联合传感器系统及其操作方法		
公开(公告)号	US20160310066A1	公开(公告)日	2016-10-27
申请号	US15/077793	申请日	2016-03-22
[标]申请(专利权)人(译)	骨伤共识		
申请(专利权)人(译)	CONSENSUS骨科，INC.		
当前申请(专利权)人(译)	CONSENSUS骨科，INC.		
[标]发明人	WIEDENHOEFER CURT CREEL JUSTIN ANTHONY KATERBERG BRIAN JAMES HOWARD JOSHUA DALE		
发明人	WIEDENHOEFER, CURT CREEL, JUSTIN ANTHONY KATERBERG, BRIAN JAMES HOWARD, JOSHUA DALE		
IPC分类号	A61B5/00 A61B5/11 A61B5/01		
CPC分类号	A61B5/4585 A61B5/0086 A61B5/0013 A61B5/0035 A61B5/01 A61B2562/0247 A61B5/6878 A61B5/112 A61B5/1121 A61B2090/309 A61B2560/0214 A61B5/0031 A61B1/00016 A61B5/024 A61B5/076 A61B5/1071 A61B5/1126 A61B5/4528 A61B5/4851 A61B5/6833 A61B5/686 A61B5/742 A61B2034/2048 A61B2505/09 A61B2562/0219 A61B2562/0223 A61B1/041 G01C21/12 G01C22/006 G01C9/00 A61B5/0015		
优先权	62/136925 2015-03-23 US 62/136892 2015-03-23 US		
外部链接	Espacenet USPTO		

摘要(译)

一种关节传感器系统包括：可植入关节相机组件;耦合到所述关节相机组件的可选数据通信设备;用于收集关节数据的数据处理装置;以及耦合到所述数据处理装置的显示器，用于使用所述关节相机组件监视所述关节接口。