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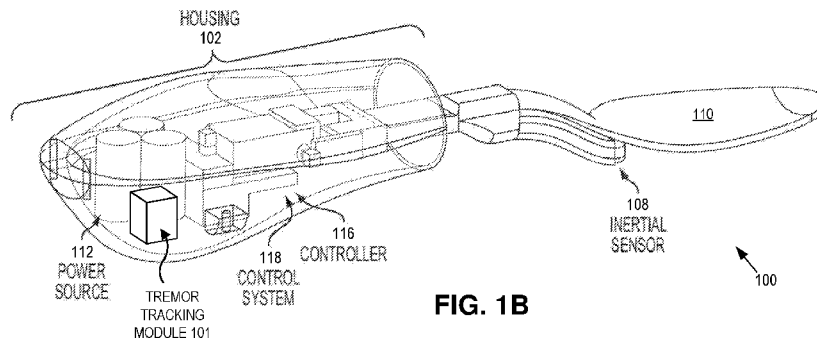
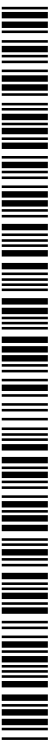


FIG. 1B

(57) Abstract: A technique for measuring and collecting human tremor data includes measuring motions of a handheld tool manipulated by a user while performing a task with the handheld tool. The motions are measured using an inertial measurement unit ("IMU") disposed within a handle of the handheld tool. Motion data of the motions is recorded to a motion log stored within a memory unit of the handheld tool. The motion data contains information for determining a severity of tremors that occurred while the user performed the task with the handheld tool. The motion log is communicated to a remote server for analysis.



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MEASUREMENT AND COLLECTION OF HUMAN TREMORS THROUGH A HANDHELD TOOL

TECHNICAL FIELD

[0001] This disclosure relates generally to unintentional muscle movements, and in particular but not exclusively, relates to the measurement and tracking of unintentional muscle movements.

BACKGROUND INFORMATION

[0002] Movement disorders are often caused by chronic neurodegenerative diseases such as Parkinson's Disease ("PD") and Essential Tremor ("ET"). Both of these conditions are currently incurable and cause unintentional muscle movements or human tremors—uncontrollable rhythmic oscillatory movements of the human body. In many cases human tremors can be severe enough to cause a significant degradation in quality of life, interfering with daily activities/tasks such as eating, drinking, or writing.

[0003] Patients with movement disorders are typically diagnosed in a clinic using scales such as the Fahn–Tolosa–Marin Tremor Rating Scale for ET or the Unified Parkinson Disease (UPDRS) rating scale for PD. Both of these scales require a trained neurologist to complete and often rely on subjective assessments that occur over a brief period of time in the practitioner's office. Symptom severity at home is typically evaluated from the patient's self-reporting, which is also highly subjective and prone to error. This creates significant challenges when developing and evaluating long-term treatments or interventions for these diseases.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Non-limiting and non-exhaustive embodiments of the invention are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles being described.

[0005] FIGs. 1A is a cross-sectional illustration of a handheld tool that measures and tracks unintentional muscle movements, in accordance with an embodiment of the disclosure.

[0006] FIG. 1B is a perspective view illustration of the handheld tool that measures and tracks unintentional muscle movements, in accordance with an embodiment of the disclosure.

[0007] FIG. 2 is a functional block diagram illustrating a tremor tracking module, in accordance with an embodiment of the disclosure.

[0008] FIG. 3 is a flow chart illustrating a process for measuring, tracking, and analyzing unintentional muscle movements using a handheld tool, in accordance with an embodiment of the disclosure.

[0009] FIG. 4 illustrates an example rigid body assumption of a handheld tool, in accordance with an embodiment of the disclosure.

[0010] FIG. 5 is a perspective view illustration of a motion generating mechanism of a handheld tool that compensates for unintentional muscle movements, in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

[0011] Embodiments of an apparatus, system and process for measuring, tracking, and analyzing unintentional muscle movements of a user while using a handheld tool to perform an ordinary activity are described herein. In the following description numerous specific details are set forth to provide a thorough understanding of the embodiments. One skilled in the relevant art will recognize, however, that the techniques described herein can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring certain aspects.

[0012] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0013] FIGs. 1A and 1B illustrate a handheld tool 100 that measures and tracks unintentional muscle movements, in accordance with an embodiment of the disclosure. FIG. 1A is a cross-sectional illustration of handheld tool 100 while FIG. 1B is a perspective view illustration of the same. Handheld tool 100 is also capable of detecting and compensating for unintentional muscle movement (tremors); however, it should be appreciated that various embodiments need not include the mechanisms and associated sensors for tremor compensation to implement the measurement, tracking, and/or diagnosing of tremors, even though both features are incorporated into the illustrated embodiment of handheld tool 100. Accordingly, the illustrated embodiment of handheld tool 100 includes a subsystem for measuring and

tracking user tremors (e.g., a tremor tracking module) and a subsystem for detecting and compensating for those same tremors. These subsystems may have distinct components, or share some components such as power systems, memory, a controller, and may even share one or more sensors. In some embodiments, one or more components of the subsystem for detecting and compensating for tremors may be omitted.

[0014] Handheld tool 100 includes a housing 102, which functions as a handle for holding handheld tool 100. Handheld tool 100 also includes an attachment arm 106 coupled to the housing 102. Attachment arm 106 is configured to accept a user-assistive device 110 (e.g., a spoon in the illustrated embodiment) to its end distal from housing 102. Handheld tool 100 further includes a tremor tracking module (“TTM”) 101 for measuring and tracking tremors. One or more components of TTM 101 are rigidly attached to housing 102 to measure and track tremors of the handle that the user holds. FIGs. 1A and 1B illustrate TTM 101 as a single block within housing 102; however, in other embodiments, TTM 101 includes several functional items that may assume a variety of different form factors and may further be spread throughout housing 102.

[0015] The illustrated embodiment of handheld tool 100 further includes a subsystem 104 for detecting and compensating for tremors of user-assistive device 110. In the illustrated embodiment, subsystem 104 includes at least one inertial sensor 108 placed along attachment arm 106 to measure absolute movement of attachment arm 106 and user-assistive device 110. Subsystem 104 further includes a portable power source 112, a motion-generating mechanism 114, a controller 116, a control system 118, and at least one distributed motion sensor 120 for measuring relative motion of attachment arm 106 relative to housing 102. As mentioned above, TTM 101 may share one or more of the components of subsystem 104 (e.g., power source 112, controller 116, etc.). In other embodiments, one or more of the components of subsystem 104 for compensating tremor motions may also be omitted (e.g., inertial sensor 108, motion-generating mechanism 114, etc.) while still implementing the tremor measurement and tracking functionality disclosed herein.

[0016] In one embodiment, attachment arm 106 is integrated with a specific type of user-assistive device 110 (spoon illustrated). In other embodiments, attachment arm 106 can receive a variety of different user-assistive devices 110 in a variety of ways including but not limited to a friction, snap, or other form of locking mechanism. Portable power source 112 may utilize a variety of options including but not limited to a rechargeable battery, a solar panel, etc.

[0017] The at least one inertial sensor 108 and the at least one distributed motion sensor 120 detect unintentional muscle movements and measure signals related to these

unintentional muscle movements that are created when a user adversely affects motion of user-assistive device 110. These sensors also detect the motion of the stabilized output relative to the housing 102. Control system 118 sends voltage commands in response to the signals to the motion-generating mechanism 114 through the controller 116 to cancel the user's tremors or unintentional muscle movements. This cancellation maintains and stabilizes a position of the user-assistive device 110, keeping it centered relative to the housing 102.

[0018] One of ordinary skill in the art readily recognizes that a system and method in accordance with the present disclosure may utilize various implementations of controller 116, at least one inertial sensor 108, at least one distributed motion sensor 120, and control system 118 and that would be within the spirit and scope of the present disclosure. In one embodiment, controller 116 comprises an electrical system capable of producing an electrical response from sensor inputs such as a programmable microcontroller a field-programmable gate array (FPGA), an application specific integrated circuit ("ASIC"), or otherwise. In one embodiment, controller 116 comprises an 8-bit ATMEGA8A programmable microcontroller manufactured by Atmel due to its overall low-cost, low-power consumption and ability to be utilized in high-volume applications.

[0019] In one embodiment, the at least one inertial sensor 108 is a sensor including but not limited to an accelerometer, gyroscope, or combination of the two. In one embodiment, the at least one distributed motion sensor 120 is a contactless position sensor including but not limited to a hall-effect magnetic sensor. In one embodiment, the control system 118 is a closed-loop control system.

[0020] The closed-loop control system senses motion and acceleration at various points along handheld tool 100 and feeds detailed information into a control algorithm that moves motion-generating mechanism 114 appropriately to cancel the net effect of a user's unintentional muscle movements and thus stabilize the position of user-assistive device 110.

[0021] One of ordinary skill in the art will readily recognize that an apparatus, a system, or method as described herein may be utilized for a variety of applications. For example, various different user-assistive devices 110 may include a manufacturing tool, a surgical tool, a kitchen utensil (e.g., fork, knife, spoon), a sporting tool, a yard tool, a grooming tool (e.g., comb, nail clippers, tweezers, make-up applicator, etc.), or a dental hygiene tool (e.g., toothbrush, flossing tool, etc.). Thus, handheld tool 100 may be useful in not only improving the quality of life for the multitudes of individuals suffering from neurological motion disorders, but also in assisting in a variety of applications where physiological tremor is an issue including but not limited to manufacturing, surgical and public safety applications.

[0022] In one embodiment, handheld tool 100 stabilizes user-assistive device 110 about a neutral position (for example, $\theta = 0$ may be selected or otherwise) using the at least one inertial sensor 108. To achieve this, the position of user-assistive device 110 is sensed along with the angle θ . For this position sensing, the at least one inertial sensor 108 is placed along the attachment arm 106 and is used to measure the absolute motion of the user-assistive device 110 while providing low noise and sufficient sensitivity for the application. The direct sensor placement of the at least one inertial sensor 108 along attachment arm 106 gives a unique advantage to handheld tool 100 as it is extremely robust and does not rely on inverse kinematics/dynamics which may change depending on usage. Thus, as aforementioned, a variety of objects can be used to implement user-assistive device 110 without the need to pre-determine and pre-program the length and weight of user-assistive device 110 into the controller 116.

[0023] In the illustrated embodiment, the at least one distributed motion sensor 120 is located within the housing 102 which is located at the base of the handheld tool 100. The at least one distributed motion sensor 120 measures the relative motion of attachment arm 106 relative to the housing 102, wherein user-assistive device 110 is kept at a center position relative to housing 102. In one embodiment, the at least one distributed motion sensor 120 is at least one contactless hall-effect position sensor that provides angular feedback for control system 118 and relies on a changing magnetic field that is dependent on the actuation angle.

[0024] The changing magnetic field is detected by a strategically placed integrated circuit (IC) located within the at least one distributed motion sensor 120, whose analog output is read by controller 116, providing a completely non-contact angular detection that is capable of withstanding a large number of cycles. The at least one distributed motion sensor 120, with its contactless sensing methods, provides improved reliability over conventional direct-contact sensing methods such as potentiometers that wear over time.

[0025] In one embodiment, handheld tool 100 uses a combination of coreless micro-motors and miniature gear-reduction systems coupled to the coreless micro-motors using a coupling mechanism to implement motion-generating mechanism 114. Significant force of up to 10 newtons (N) can also be produced with these coreless micro-motors at the required tremor frequency of 0-5 hertz (Hz) through the use of a low-cost miniature gear-reduction system, with a total weight of only 6.5 grams (g). Furthermore, the power drawn from this technology is low, estimated at 0.5 watts (W).

[0026] FIG. 2 is a functional block diagram illustrating a TTM 200, in accordance with an embodiment of the disclosure. TTM 200 is one possible implementation of TTM 101

illustrated in FIGs. 1A and 1B. The illustrated embodiment of TTM 200 includes an inertial measurement unit (“IMU”) 205, a controller 210, a memory unit 215, and a communication interface 220.

[0027] IMU 205 is disposed in rigid contact with housing 102 to directly measure the tremor motions of the handle and by extension the tremor motions of the user’s hand. TTM 200 facilitates the measurement of human tremors while a user is performing an everyday task, such as eating or grooming (e.g., applying makeup). This is an important distinction over conventional in-clinic evaluations that simply measure the tremor of a hand that a patient is attempting to hold steady. Measurement and tracking of tremors while the patient is performing an everyday task measures the condition under real-world scenarios that are most adversely impacted by human tremors. Accordingly, TTM 200 can be embedded within everyday items or tools that are used routinely by patients to accurately measure and track their condition. This can lead to improved evaluations.

[0028] Not only can handheld tool 100 measure and track human tremors during a routine task, but it can conveniently do so over a period of time to obtain a more reliable dataset for statistical analysis. Furthermore, handheld tool 100 can be used at home where the user is more relaxed and under less stress than a formal evaluation in a practitioner’s office. Data collection within the home environment along with larger datasets than can be obtained in-clinic, can provide more reliable data for evaluation of a patient’s symptoms. Improved evaluation and diagnosis of the patient’s tremors facilitate improved treatments and interventions of the various diseases and the conditions that cause human tremors.

[0029] IMU 205 may be implemented using variety of devices that measure motions of the handle of handheld tool 100. For example, IMU 205 may include one or more accelerometers that measure linear accelerations. In one embodiment, IMU 205 includes accelerometers capable of measuring translational accelerations of the handle in three orthogonal dimensions (e.g., x, y, and z dimensions). In one embodiment, IMU 205 includes a gyroscope to measure rotational motions (e.g., angular velocity about an axis) of the handle of handheld tool 100. In various embodiments, the gyroscope may be capable of measuring the rotational motions about one, two, or three orthogonal rotational axes. In one embodiment, IMU 205 includes a magnetometer to measure motions of the handle relative to a magnetic field (e.g., Earth’s magnetic field or other externally applied magnetic field). In various embodiments, IMU 205 may include various combinations of some or all of the above listed motion measuring devices. Furthermore, these motion sensors may be disposed together on a common substrate that is rigidly attached to housing 102, or disposed throughout housing 102.

[0030] Controller 210 is communicatively coupled to IMU 205 and memory unit 215 to read motion data output from IMU 205 and store the motion data into memory unit 215. The motion data is collected over a period of time. For example, the motion data may be collected while the user performs an individual task, over the course of a day, a week, or other period of time. The collected motion data stored in memory unit 215 forms a motion log 225. In one embodiment, motion log 225 may contain enough information about the user's motions (linear accelerations, rotational velocities, durations of these accelerations/velocities, orientation relative to a magnetic field, etc.), based upon the motion data output from IMU 205, to recreate those motions using motion log 225. In one embodiment, motion log 225 may also record date/time stamps of when the motion data was collected and even include identifiers indicating the type of user-assistive device 110 that was attached to the handheld 100 when the motion data was collected. The type identifier provides an indication of the activity (e.g., eating with a fork, knife, or spoon, etc.) being performed by the user when the motion data was collected. This activity information and time/date stamps may be useful for the practitioner when evaluating the patient's motion log 225 to determine if the patient's tremors correlate to particular activities or time of day. In yet other embodiments, motion log 225 may also record battery voltage as a function of date/time, which may be used to analyzing system performance and battery usage. Tracking battery voltage is a sort of proxy for the amount of effort exerted by motion-generating mechanism 114 to stabilize user-assistive device 110. As such, tracking battery voltage or battery consumption correlates to the degree of a user's tremors since battery consumption will rise with increased tremors.

[0031] Controller 210 may be implemented with a programmable microcontroller, an FPGA, an ASIC, or other devices capable of executing logical instructions. The logical instructions themselves may be hardware logic, software logic (e.g., stored within memory unit 215 or elsewhere), or a combination of both. Memory unit 215 may be implemented using volatile or non-volatile memory (e.g., flash memory).

[0032] Communication interface 220 is communicatively coupled to output the motion log 225 from memory unit 215 to remote server 230 via network 235 (e.g., the Internet). In one embodiment, communication interface 220 is a wireless communication interface (e.g., Bluetooth, WiFi, etc.). For example, communication interface 220 may establish a wireless link to a user's cellular phone which delivers motion log 225 to server 230 via an installed tremor tracking application. The application may enable the user to control privacy settings, add comments about their usage of handheld tool 100, setup automatic periodic reporting of motion log 225, initiate a one-time reporting of motion log 225, along with other user functions. In yet

another embodiment, communication interface 220 may be a wired communication port (e.g., USB port). For example, when the user connects handheld tool 100 to a charging dock to charge power source 112, communication interface 220 may also establish a communication session with remote server 230 for delivery of motion log 225 thereto.

[0033] FIG. 3 is a flow chart illustrating a process 300 for measuring, tracking, and analyzing unintentional muscle movements (tremors) using handheld tool 100, in accordance with an embodiment of the disclosure. The order in which some or all of the process blocks appear in process 300 should not be deemed limiting. Rather, one of ordinary skill in the art having the benefit of the present disclosure will understand that some of the process blocks may be executed in a variety of orders not illustrated, or even in parallel.

[0034] In a process block 305, a patient (user) uses handheld tool 100 to perform a task or activity, such as a routine everyday activity including eating or grooming. Of course, handheld tool 100 may also be used for other non-routine activities, as described above. While performing this activity, TTM 101 measures the patient's motions as the patient manipulates handheld tool 100 (process block 310). TTM 101 directly measures the motions, including tremors, of the handle of handheld tool 100. In some embodiments, handheld tool 100 may also perform simultaneous active stabilization of user-assistive device 110 to reduce the impact of the patient's human tremors. In other embodiments, handheld tool 100 either does not include active stabilization or the active stabilization functionality may be disabled.

[0035] While the patient manipulates handheld tool 100, IMU 205 actively measures the tremors and outputs motion data indicative of the user's motions, including their tremors. In one embodiment, the sensors of IMU 205 are sampled at a rate of 50 times per second. Of course, other sampling rates may be implemented. In process block 315, the motion data is stored into memory unit 215 as motion log 225. In one embodiment, the generation of motion log 225 within memory unit 215 is orchestrated by controller 210. As mentioned above, motion log 225 may be populated with additional information such as time/date stamps, type of user-assistive device 110 attached to attachment arm 106, or otherwise. The type of user-assistive device 110 may be collected by incorporation of an electronic readable identifier (e.g., RFID tag, an electronic readable serial number, etc.) disposed in or on user-assistive device 110, by user input using a cellular phone application, or otherwise. In one embodiment, motion log 225 is further populated with data that is indicative of an amount of correction imparted by motion-generating mechanism 114 and/or sensor data from inertial sensor 108 and distributed motion sensors 120. This additional data contains information about how much stabilization handheld

tool 100 imparted while the user performed a given task and can provide useful information for analyzing the user's tremors.

[0036] In a process block 320, TTM 101 reports motion log 225 to remote server 230 via communication interface 220 and network 235. The reporting of motion log 225 may be periodic, user initiated, initiated when memory unit 215 reaches a threshold capacity, initiated when handheld tool 100 is charged, or otherwise. In one embodiment, controller 210 facilitates the transmission of motion log 225 out communication interface 220 in cooperation with an external user application.

[0037] In a process block 325, remote server 230 analyzes motion log 225 to recreate the user motions, including the tremor motions, recorded while the user manipulated handheld tool 100 while performing a task. Transmission of motion log 225 to remote server 230 enables in-home data collection and external analysis and evaluation of the patient's condition.

[0038] The analysis of the motion data within motion log 225 may be performed using a variety of different algorithms to estimate the user's motion. For example, in a case where IMU 205 includes a tri-axial accelerometer and a tri-axial gyroscope the following analysis is one example analysis that can be performed by remote server 230.

[0039] Since an accelerometer and a gyroscope do not directly sense the user's hand position, equations of motion are used to estimate the amplitude and frequency of the user's hand tremor. The below equations account for errors introduced in the accelerometer signals -- due to centripetal acceleration and gravitational artifacts introduced by tilt. Once these errors are removed, the acceleration data is transformed from the time domain into the frequency domain, using a Fast Fourier Transform ("FFT"). By extracting the peak of the resulting spectrum, the dominant tremor frequency can be calculated as well as an estimate of the amplitude of the hand's acceleration. Equations of motion for vibrating objects can be used to then calculate the amplitude of the hand's position.

[0040] In one embodiment, we can start by modeling handheld tool 100 as a rigid body undergoing both translational and rotational motion. FIG. 4 illustrates an example rigid body assumption for handheld tool 100. Point A is where IMU 205 is positioned (sensing angular rate and acceleration), and point B is where motion is being estimated (tip of a spoon, for example). The acceleration at point B can be related to the acceleration at A with the following equations:

$$\ddot{B}_x = \ddot{A}_x - r\dot{\theta}_z^2 - r\dot{\theta}_y^2 + g\theta_y \quad (\text{Equation 1})$$

$$\ddot{B}_y = \ddot{A}_y + r\ddot{\theta}_z + g\theta_x \quad (\text{Equation 2})$$

$$\ddot{B}_z = \ddot{A}_z + r\ddot{\theta}_y \quad (\text{Equation 3})$$

[0041] The terms leading to error include the terms for centripetal acceleration (Equation 1) as well as terms due to the gravitational vector shifting due to tilt (Equations 1 and 2). The latter error source relies on estimates of the device's pitch and roll (defined as θ_y and θ_x).

[0042] The motion of point B by can be estimated as a single-frequency sinusoid (due to human tremor) with the following solution (using a trig identity):

$$B(t) = \bar{B}[\cos(\omega t) + i\sin(\omega t)] = \bar{B}e^{i\omega t} \quad (\text{Equation 4})$$

The same can be written for angular rotation:

$$\theta(t) = \bar{\theta}[\cos(\omega t) + i\sin(\omega t)] = \bar{\theta}e^{i\omega t} \quad (\text{Equation 5})$$

Using the exponential form and taking the time derivatives gives (for Equation 4):

$$\dot{B}(t) = \bar{B}i\omega e^{i\omega t} \quad (\text{Equation 6})$$

and

$$\dot{\theta}(t) = \bar{\theta}(-\omega^2)e^{i\omega t} \quad (\text{Equation 7})$$

where \bar{B} is the amplitude of the sinusoid and ω is the angular frequency.

[0043] Two relationships can be obtained by inspecting Equation 4, 6, and 7. First, for a single sinusoid, the angular rate is proportional to displacement signal, scaled by the sinusoidal frequency and shifted 90 degrees out of phase. The second relationship is that the acceleration is the negative of the displacement signal, scaled by the square of the frequency.

[0044] A first order estimate of the user's motion can be done from the assumption that 1) the handheld tool 100 is a rigid body and 2) the tremor is sinusoidal in nature. From the first assumption, the motion of the tip of a rigidly connected spoon can be calculated from the following relationship:

$$B_i = A_i + L\sin\theta_j \quad (\text{Equation 8})$$

i is the axis of interest (x , y , z), and j is the orthogonal axis of rotation inducing the motion.

Equations 1, 2, and 3, can be used to estimate the motion of A (correcting for the terms introducing error). The amplitude of A and θ can be estimated by taking the FFT of the accelerometer and gyroscope signals, finding the peak, and then using the relationships of Equations 6 and 7 to calculate the magnitude of B .

[0045] The orientation of handheld tool 100 (relative to an inertial coordinate system) using the accelerometer and gyroscope signals can be performed. One way to accomplish pitch and roll estimation is to estimate a gravitational vector through a combination of a low pass

filter of the accelerometer sensor and an integration of the gyroscope sensor. To calculate the pitch and roll of the device, rotation matrices are used to estimate the following equations:

For pitch:

$$\tan\theta_y = \frac{-g_x}{\sqrt{g_y^2 + g_z^2}} \quad (\text{Equation 9})$$

and for roll:

$$\tan\theta_x = \frac{g_y}{g_z} \quad (\text{Equation 10})$$

The vector g is calculated through a complementary filter (can also use a Kalman filter), using both the gyroscope and accelerometer signals as inputs. An alternate way to estimate the pitch and roll angles is to use a magnetometer as a third sensor input. It should be appreciated that the above analysis is only one example of analyzing motion log 225 to recreate the motions of handheld tool 100. Other techniques may be implemented.

[0046] Returning to process 300 illustrated in FIG. 3, remote server 230 extracts a tremor score from the recreated hand motions, in a process block 330. For example, the tremor score may be based upon the frequency and amplitude of the user's tremors as determined by the above analysis. In process block 335, the tremor score is correlated to a known clinical scale, such as the Fahn–Tolosa–Marin Tremor Rating Scale or the Unified Parkinson Disease (UPDRS) rating scale.

[0047] Finally, a report of the patients results, including their tremor score, is communicated to the practitioner treating the patient. In one embodiment, this report is communicated electronically over the Internet in a secure manner to the practitioner.

[0048] FIG. 5 is a perspective view illustration of a motion generating mechanism 500 of a handheld tool that compensates for unintentional muscle movements, in accordance with an embodiment of the disclosure. Motion generating mechanism 500 is one possible implementation of motion generating mechanism 114 illustrated in FIGs. 1A and 1B.

[0049] Motion-generating mechanism 500 includes a first miniature gear-reduction system coupled to a first coreless micro-motor 502 and a second miniature gear-reduction system coupled to a second coreless micro-motor 504. At least one inertial sensor 508 is placed along an attachment arm 506. The attachment arm 506 is configured to accept a user-assistive device 510 thereto.

[0050] The first coreless micro-motor is capable of producing rotary motion in the horizontal (x) direction. This rotary motion is imparted to the second coreless micro-motor through a rigid connection that is supported by a horizontal bearing. The second coreless

micro-motor is capable of producing motion in the vertical (y) direction. This motion from the second coreless micro-motor is supported by a vertical bearing.

[0051] A coupling mechanism is used to combine the horizontal and vertical motions of the two separate coreless micro-motor/miniature gear-reduction systems 502 and 504. This combination results in a bi-directional circular motion of the user-assistive device 510 (in the illustrated embodiment, a spoon). One of ordinary skill in the art readily recognizes that a system and method in accordance with the present disclosure may utilize a variety of coupling mechanisms including but not limited to sliding bearing mechanisms, gimbal structures, or bellows structures and that would be within the spirit and scope of the present disclosure.

[0052] In the motion-generating mechanism 500, two degrees of freedom are generated from the two separate coreless micro-motor/miniature gear-reduction systems 502 and 504. Additional degrees of freedom (e.g., a third in the z-direction) can be added to the motion-generating mechanism 500 by adding motion to the output of the first coreless micro-motor or the output of the second coreless micro-motor.

[0053] The processes explained above are described in terms of computer software and hardware. The techniques described may constitute machine-executable instructions embodied within a tangible or non-transitory machine (e.g., computer) readable storage medium, that when executed by a machine will cause the machine to perform the operations described. Additionally, the processes may be embodied within hardware, such as an application specific integrated circuit (“ASIC”) or otherwise.

[0054] A tangible machine-readable storage medium includes any mechanism that provides (i.e., stores) information in a non-transitory form accessible by a machine (e.g., a computer, network device, personal digital assistant, manufacturing tool, any device with a set of one or more processors, etc.). For example, a machine-readable storage medium includes recordable/non-recordable media (e.g., read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, etc.).

[0055] The above description of illustrated embodiments of the invention, including what is described in the Abstract, is not intended to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

[0056] These modifications can be made to the invention in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification. Rather, the scope of the

invention is to be determined entirely by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

What is claimed is:

1. A handheld tool, comprising:
 - a handle;
 - an attachment arm extending from the handle;
 - a user-assistive device attached to a distal end of the attachment arm;
 - an inertial measurement unit (“IMU”) rigidly attached to the handle to measure motions of the handle and to generate motion data indicative of the motions of the handle; and
 - a communication interface to output the motion data from the handheld tool.
2. The handheld tool of claim 1, wherein the IMU includes an accelerometer to measure translational accelerations of the handle.
3. The handheld tool of claim 2, wherein the IMU further includes a gyroscope to measure rotational motions of the handle.
4. The handheld tool of claim 2, wherein the in the IMU further includes a magnetometer to measure motions of the handle relative to a magnetic field.
5. The handheld tool of claim 1, further comprising:
 - a controller coupled to the IMU to read the motion data from the IMU;
 - a memory unit coupled to the controller; and
 - logic executable by the controller that when executed by the controller causes the handheld tool to perform operations comprising:
 - generating a motion log within the memory unit based upon the motion data generated while a user is holding the handheld tool.
6. The handheld tool of claim 5, wherein the logic includes further logic that when executed by the controller causes the handheld tool to perform further operations comprising:
 - generating multiple motion logs within the memory unit based upon the motion data generated while the user is holding the handheld tool and performing one or more activities.

7. The handheld tool of claim 6, wherein the user-assistive device comprises a kitchen utensil and wherein the one or more activities comprise eating.

8. The handheld tool of claim 6, wherein the logic includes further logic that when executed by the controller causes the handheld tool to perform further operations comprising:
recording a type of the user-assistive device mounted on the attachment arm with the motion logs as an indication of the one or more activities performed by the user when recording the motion data.

9. The handheld tool of claim 5, wherein the communication interface comprises a wireless interface, and wherein the logic includes further logic that when executed by the controller causes the handheld tool to perform further operations comprising:

wirelessly communicate the motion log to a remote server using the communication interface.

10. The handheld tool of claim 5, further comprising:

a motion-generating mechanism disposed within the handle;

a first motion sensor disposed on the attachment arm to detect tremor motions of the attachment arm; and

a second motion sensor disposed within the handle to detect relative motion of the attachment arm relative to the handle,

wherein the attachment arm moves relative to the handle under influence of the motion-generating mechanism with feedback from the first and second motion sensors to stabilize the tremor motions.

11. The handheld tool of claim 10, wherein the logic includes further logic that when executed by the controller causes the handheld tool to perform further operations comprising:

recording additional data into the motion log that is indicative of an amount of correction imparted by the motion-generating mechanism on the attachment arm while stabilizing the tremor motions.

12. The handheld tool of claim 1, wherein the user-assistive device comprises any of a manufacturing tool, a surgical tool, a kitchen utensil, a sporting tool, a yard tool, a grooming utensil, or a dental hygiene tool.

13. A method performed by a handheld tool, the method comprising:
measuring motions of a handheld tool manipulated by a user while performing a task with the handheld tool, wherein the motions are measured using an inertial measurement unit (“IMU”) disposed within a handle of the handheld tool;
recording motion data of the motions to a motion log stored within a memory unit disposed on-board of the handheld tool, wherein the motion data contains information for determining a severity of tremors that occurred while the user performed the task with the handheld tool; and
communicating the motion log to a remote server for analysis.
14. The method of claim 13, wherein the IMU includes sensors to measure both translational and rotational motions of the handheld tool.
15. The method of claim 14, wherein the IMU includes one or more of an accelerometer, a gyroscope, or a magnetometer being rigidly mounted to the handle of the handheld tool.
16. The method of claim 13, wherein the handheld tool comprises a kitchen utensil and the task comprises eating with the kitchen utensil.
17. The method of claim 13, wherein the handheld tool includes an attachment arm for removeably attaching different user-assistive devices to a distal end of the attachment arm, the method further comprising:
recording a type of the user-assistive device coupled to the distal end of the attachment arm while performing the task with the motion log; and
communicating the type of the user-assistive device with the motion log to the remote server.
18. The method of claim 17, wherein the type of the user-assistive device includes an indication of at least one of a fork, a knife, or a spoon.
19. The method of claim 13, wherein communicating the motion log to the remote server for analysis comprises:

establishing a wireless linking to a cellular phone; and
uploading the motion log to the server over the wireless link in response to user commands received from the cellular phone via the wireless link.

20. The method of claim 13, wherein communicating the motion log to the remote server for analysis comprises:

communicating the motion log to the remote server upon the handheld tool being coupled to a charging dock that charges an internal battery of the handheld tool.

21. The method of claim 13, wherein the handheld tool includes a motion-generating mechanism that stabilizes tremor motions while the user holds the handle.

22. The method of claim 21, further comprising:

recording data into the motion log that is indicative of an amount of correction imparted by the motion-generating mechanism while stabilizing the tremor motions.

23. A method, comprising:

receiving a motion log from a handheld tool over a network, wherein the motion log includes motion data indicative of motions of a handheld tool manipulated by a patient while performing a task with the handheld tool;

analyzing the motion data within the motion log; and

determining a severity of tremors that occurred while the user performed the task with the handheld tool based upon the motion data.

24. The method of claim 23 further comprising:

communicating an indication of the severity of the tremors to a medical practitioner treating the patient via the network.

25. The method of claim 24, wherein the analyzing comprises correlating the motion data to a clinical scale for grading human tremors, wherein the indication comprises a score on the clinical scale.

26. The method of claim 23, wherein the motion data within the motion log is generated by the patient using the handheld tool at home.

27. The method of claim 23, wherein the handheld tool comprise a kitchen utensil and the task comprises eating.

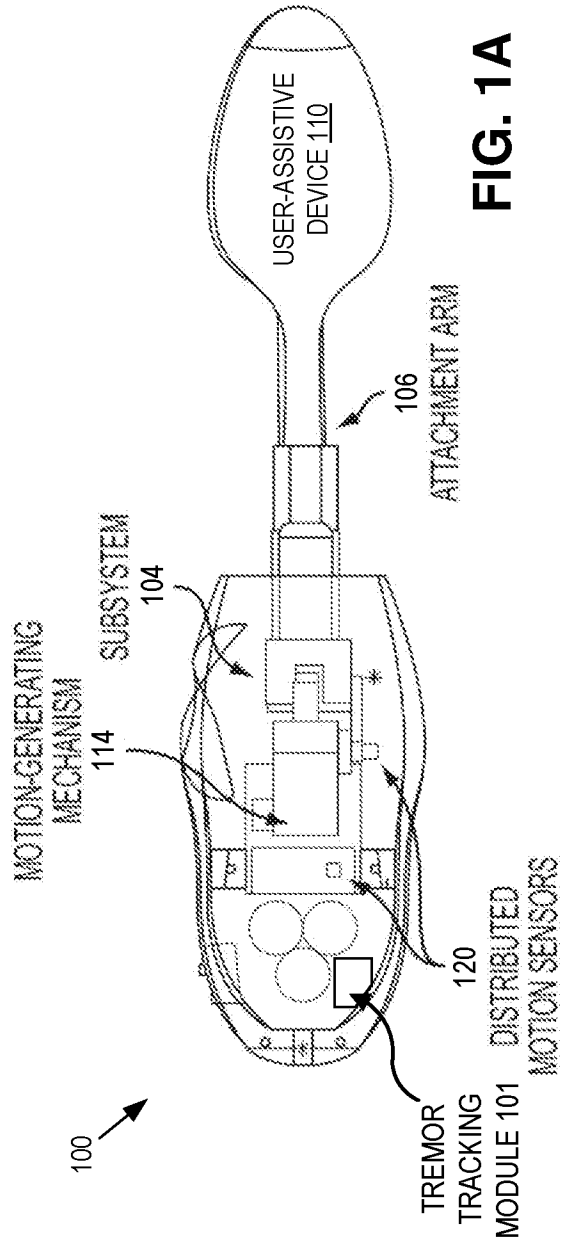


FIG. 1A

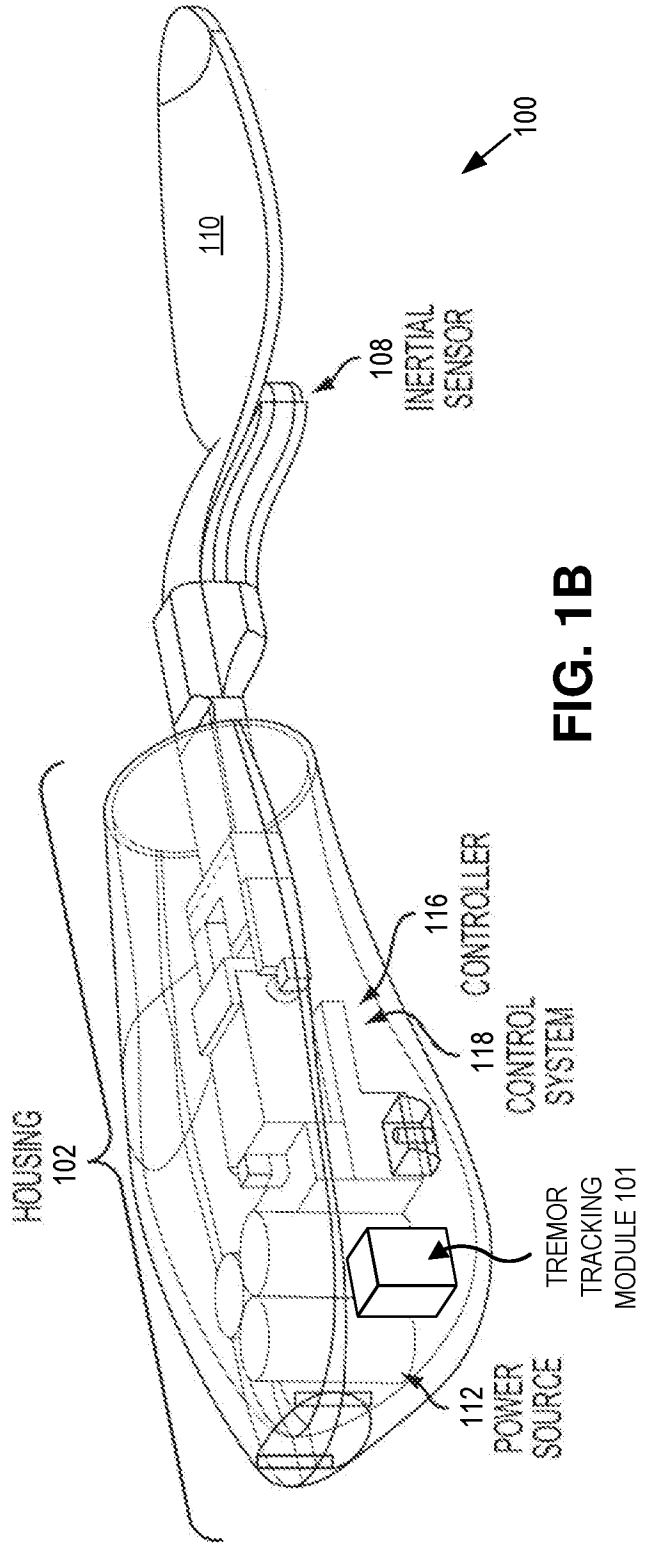


FIG. 1B

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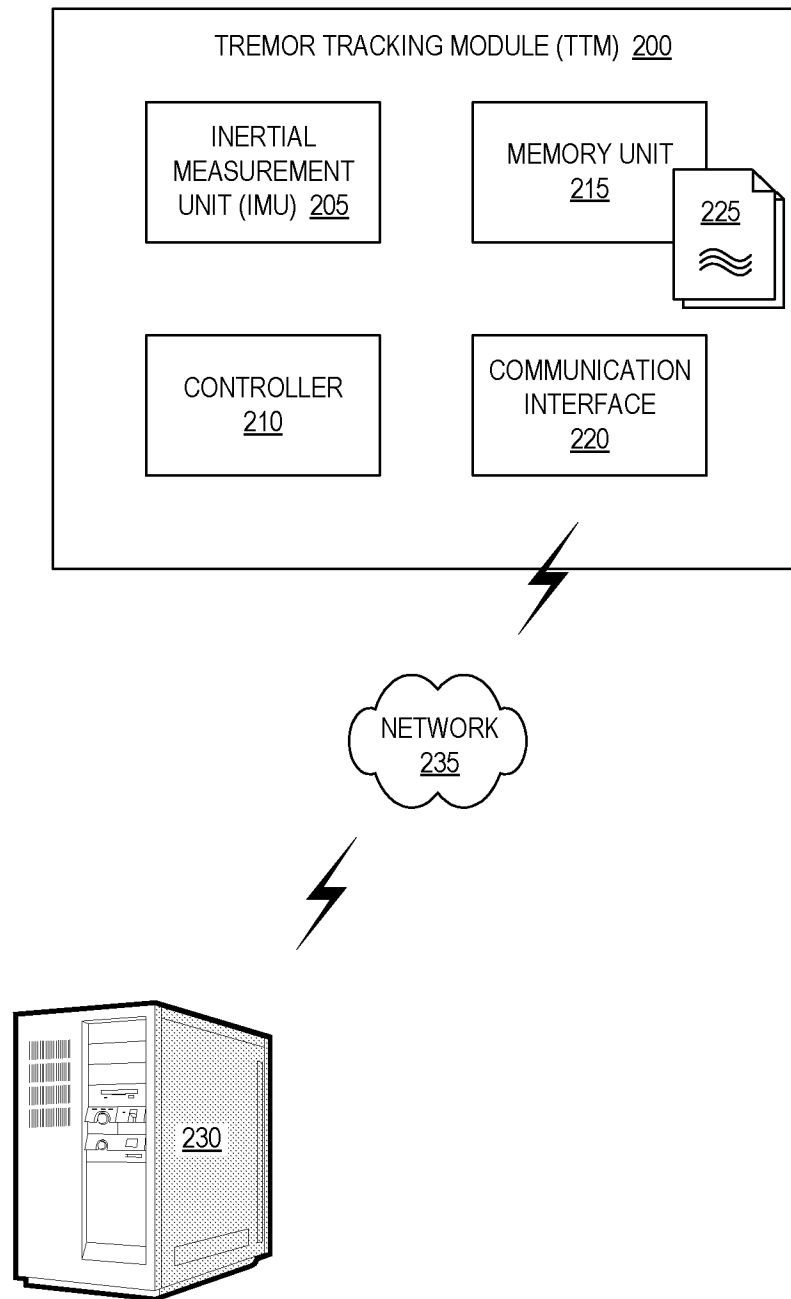


FIG. 2

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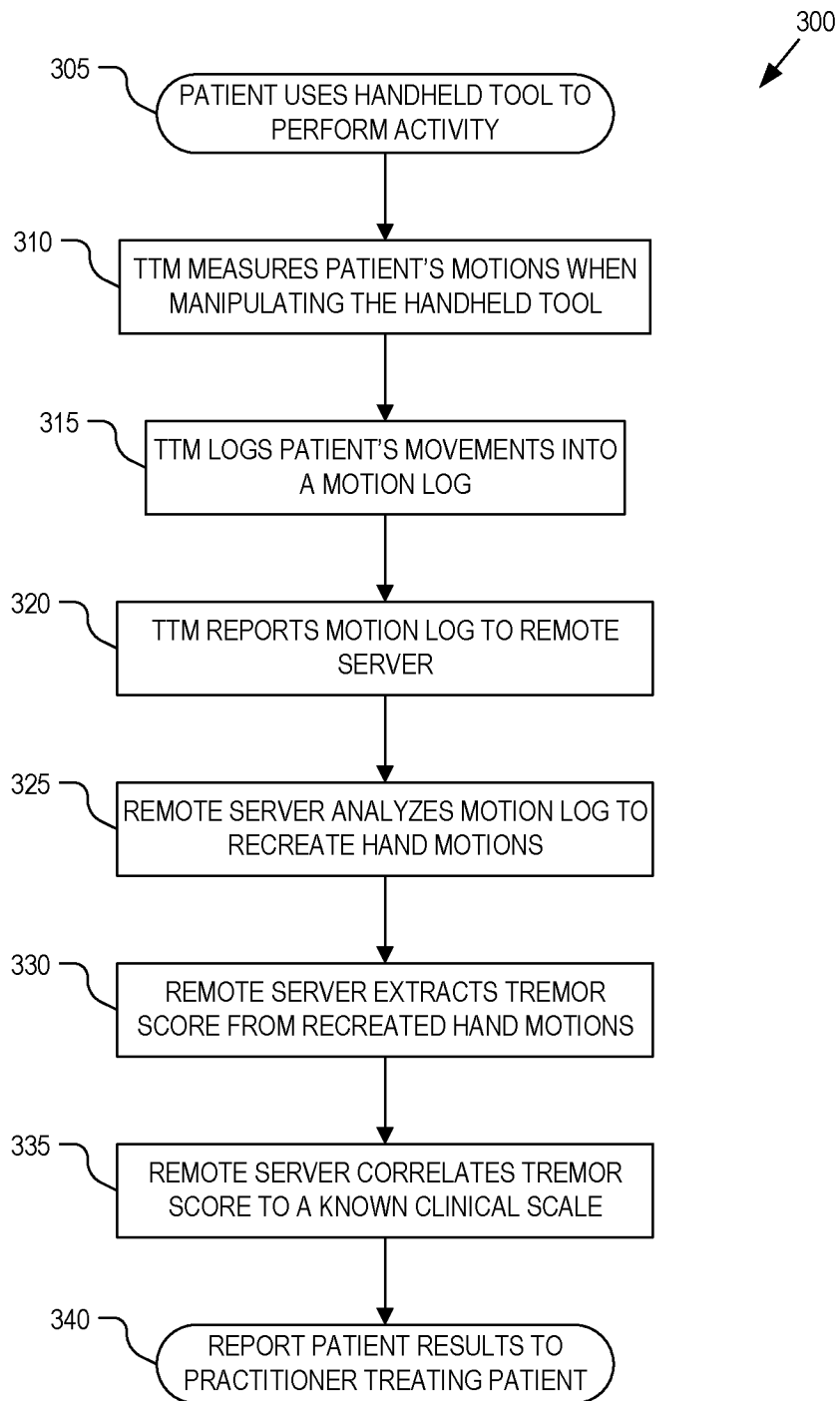


FIG. 3

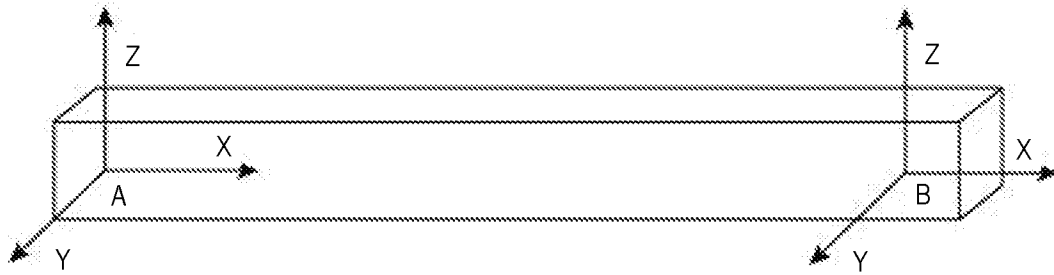


FIG. 4

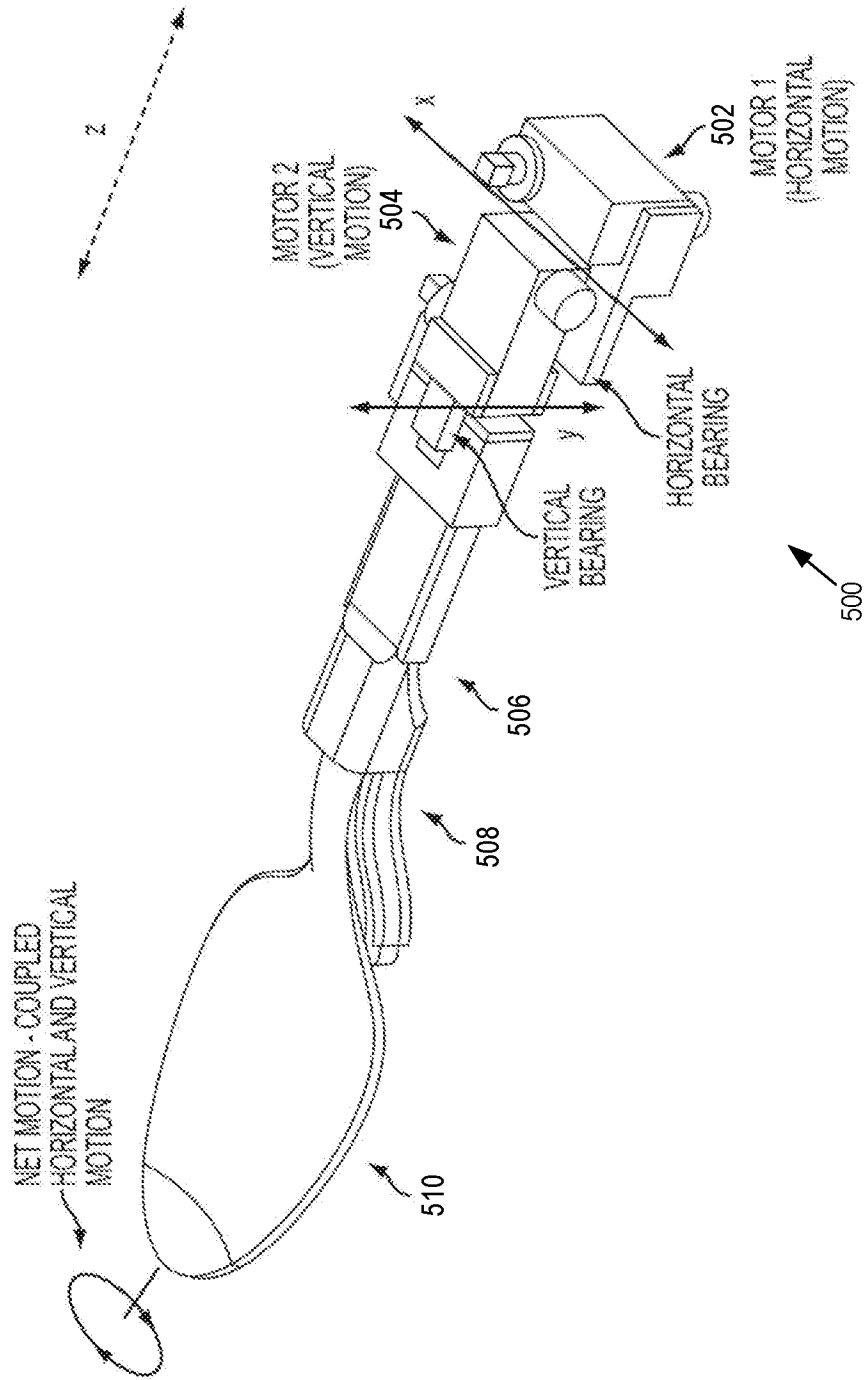


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/013704

A. CLASSIFICATION OF SUBJECT MATTER
 INV. A61B5/00 A61B5/11 F16F7/10
 ADD. A47G21/04 A61F4/00

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 A47G F16F H04N A61F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ANUPAM PATHAK ET AL: "A noninvasive handheld assistive device to accommodate essential tremor: A pilot study", MOVEMENT DISORDERS., vol. 29, no. 6, 27 May 2014 (2014-05-27), pages 838-842, XP055260616, US ISSN: 0885-3185, DOI: 10.1002/mds.25796 supporting figure 1 abstract page 839, left-hand column, line 8 section "ACT Prototype"; page 839 section "Signal Processing"; page 840 section "Discussion"; page 841 -/--	1-22

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

<p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p>	<p>"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</p> <p>"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</p> <p>"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</p> <p>"&" document member of the same patent family</p>
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Date of the actual completion of the international search 24 March 2016	Date of mailing of the international search report 06/04/2016
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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 Albrecht, Ronald
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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/013704

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	<p>& Anupam Pathak ET AL: "A noninvasive handheld assistive device to accommodate essential tremor: A pilot study: Supporting Figure",</p> <p>27 December 2013 (2013-12-27), pages 1-1, XP055260781, Retrieved from the Internet: URL:http://onlinelibrary.wiley.com/store/10.1002/mds.25796/asset/supinfo/mds25796-sup-0002-supfig1.jpg?v=1&s=ed40b3b9ef745871389a18fc26e9b150abc00d28 [retrieved on 2016-03-23] the whole document</p>	
X	<p>-----</p> <p>US 2013/060124 A1 (ZIETSMAN RUTGER CHRISTIAAN [GB]) 7 March 2013 (2013-03-07) figures 1,2,4-6 paragraphs [0049], [0050], [0052], [0075], [0081], [0096]</p> <p>-----</p>	1-3,5,6, 9,13-15
X	<p>AT 411 011 B (SAUERMAN STEFAN [AT]; LANMUELLER HERMANN [AT]; ALESCH FRANCOIS [AT];) 25 September 2003 (2003-09-25) figure 1 page 3, line 14 page 3, lines 27-30 page 3, line 53 - page 4, line 19</p> <p>-----</p>	1,2,5,6, 9,13-15
X	<p>KOSTIKIS N ET AL: "Smartphone-based evaluation of parkinsonian hand tremor: Quantitative measurements vs clinical assessment scores", 2014 36TH ANNUAL INTERNATIONAL CONFERENCE OF THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY, IEEE, 26 August 2014 (2014-08-26), pages 906-909, XP032675569, DOI: 10.1109/EMBC.2014.6943738 [retrieved on 2014-11-02] abstract section III section V</p> <p>-----</p>	13-15
A	<p>US 2014/171834 A1 (DEGOEDE KURT M [US] ET AL) 19 June 2014 (2014-06-19) paragraph [0045]</p> <p>-----</p>	4
A	<p>US 2014/052275 A1 (PATHAK ANUPAM [US]) 20 February 2014 (2014-02-20)</p> <p>claims 1-3 paragraphs [0015], [0024], [0026]</p> <p>-----</p>	4,7,8, 10,11, 16-18, 21,22
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/013704

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 203 646 979 U (PU RUQIN) 18 June 2014 (2014-06-18) the whole document in particular section "specific embodiment" figure 1 -----	7,16,21, 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/013704

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: 23-27
because they relate to subject matter not required to be searched by this Authority, namely:
see FURTHER INFORMATION sheet PCT/ISA/210
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 23-27

Rule 39.1(iv) PCT - Diagnostic method practised on the human or animal body Claim 23 includes an examination phase, involving the collection of data ("receiving a motion log"; the patient has to be examined to establish said data), the comparison of these data with standard values and the finding of any significant deviation ("analyzing the motion data [...] and determining a severity"; severity is a relative term and therefore implicitly includes the step of comparing and thereby finding deviations), and the attribution of the deviation to a particular clinical picture ("determining a severity of tremors"; severe tremor constitutes a clinical picture). Claims 23-27 are consequently considered to define a diagnostic methods carried out on the living human or animal body in the sense of Rule 39.1(iv) PCT and Rule 67.1(iv) PCT.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2016/013704

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013060124	A1	07-03-2013	CA 2799454 A1 17-11-2011
			EP 2568881 A1 20-03-2013
			JP 5784709 B2 24-09-2015
			JP 2013530735 A 01-08-2013
			US 2013060124 A1 07-03-2013
			WO 2011141734 A1 17-11-2011

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			CA 2850138 A1 04-04-2013
			CN 103906483 A 02-07-2014
			EP 2760381 A1 06-08-2014
			JP 5868512 B2 24-02-2016
			JP 2014533127 A 11-12-2014
			KR 20140082740 A 02-07-2014
			US 2014052275 A1 20-02-2014
			WO 2013049020 A1 04-04-2013

CN 203646979	U	18-06-2014	NONE
