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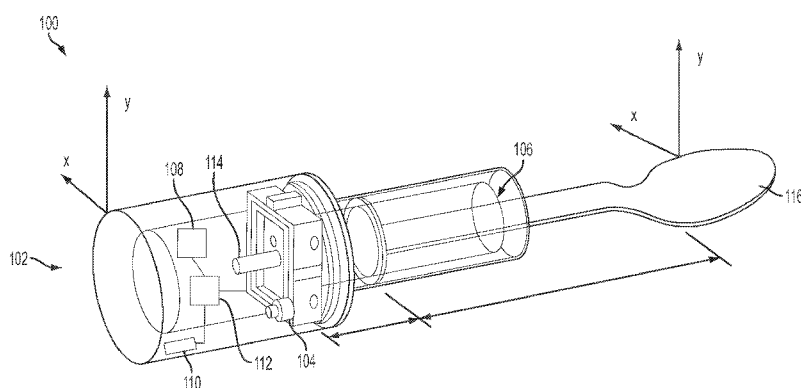


FIG. 1

(57) Abstract: A system and method for stabilizing unintentional muscle movements are disclosed. In a first aspect, a non-contact sensing system comprises a stabilization unit, at least one non-contact position sensor coupled to the stabilization unit, and a processing unit coupled to the at least one non-contact position sensor, wherein the processing unit transmits motion commands to the stabilization unit to cancel unintentional muscle movements. In a second aspect, the method comprises a processing unit of a non-contact sensing system receiving position data of a stabilization unit that is detected by at least one non-contact position sensor and filtering the position data to identify the unintentional muscle movements. The method includes modeling the position data to create a system model and determining motor commands based upon the system model to cancel the unintentional muscle movements.



STABILIZING UNINTENTIONAL MUSCLE MOVEMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent Application No. 13/250,000, September 30, 2011, entitled "SYSTEM AND METHOD FOR
5 STABILIZING UNINTENTIONAL MUSCLE MOVEMENTS," and claims the benefit of U.S. Provisional Patent Application No. 61/777,855, filed on March 12, 2013, entitled "WIRELESS SENSING AND CONTROL," all of which are incorporated herein by reference in their entireties.

10 FIELD OF THE INVENTION

The present invention relates generally to unintentional muscle movements, and more particularly, to stabilizing these unintentional muscle movements.

BACKGROUND

15 Unintentional muscle movements of the human body, or human tremors, can occur in individuals suffering from neurological motion disorders including but not limited to Parkinson's Disease (PD) and Essential Tremor (ET) and healthy individuals in stressful situations. Due to the debilitating muscle movements associated with this disease, individuals with ET have difficulty in performing many
20 daily functions such as eating and drinking. As a result, these individuals often suffer from social isolation, depression/anxiety, and an overall reduced Health Related Quality of Life (HRQoL).

For individuals suffering from unintentional muscle movements, a variety of conventional treatment options exist. Pharmacological treatments vary in effectiveness, can lead to severe side effects and are unable to slow or stop disease progression. Surgical procedures, such as Thalamotomy and thalamic
5 Deep Brain Stimulation (DBS) can be expensive, dangerous, and limited in availability. Non-invasive solutions, such as physically grounded tremor suppression devices, physically force a person's tremor to cease but require complex and costly structures, cause user discomfort and cannot differentiate between intended and unintended movements.

10 These issues limit the adoption of these treatments to select neurological motion disorder cases. Thus, for the majority of individuals that suffer from human tremor, there is a strong need for a non-invasive solution that overcomes the above issues. The present invention addresses such a need.

15 SUMMARY OF THE INVENTION

A system and method for stabilizing unintentional muscle movements are disclosed. In a first aspect, a non-contact sensing system comprises a stabilization unit, at least one non-contact position sensor coupled to the stabilization unit, and a processing unit coupled to the at least one non-contact position sensor, wherein the
20 processing unit transmits motion commands to the stabilization unit to cancel unintentional muscle movements.

In a second aspect, the method comprises a processing unit of a non-contact sensing system receiving position data of a stabilization unit that is detected by at least one non-contact position sensor and filtering the position data to identify the

unintentional muscle movements. The method includes modeling the position data to create a system model and determining motor commands based upon the system model to cancel the unintentional muscle movements.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate several embodiments of the invention and, together with the description, serve to explain the principles of the invention. One of ordinary skill in the art readily recognizes that the particular embodiments illustrated in the drawings are merely exemplary, and are not intended to limit the
10 scope of the present invention.

Figure 1 illustrates a conventional handheld system that detects and compensates for unintentional muscle movements.

Figure 2 illustrates a system that detects and compensates for unintentional muscle movements in accordance with an embodiment.

15 Figure 3 illustrates a motion-generating mechanism in accordance with an embodiment.

Figure 4 illustrates an analytical model in accordance with an embodiment.

Figure 5 illustrates a system diagram of the control system in accordance with an embodiment.

20 Figure 6 illustrates a non-contact sensing scheme in accordance with an embodiment.

Figure 7 illustrates a flowchart of a signal processing algorithm processed by a processing unit of a non-contact sensing scheme in accordance with an embodiment.

DETAILED DESCRIPTION

The present invention relates generally to unintentional muscle movements, and more particularly, to stabilizing these unintentional muscle movements. The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred embodiment and the generic principles and features described herein will be readily apparent to those skilled in the art. Thus, the present invention is not intended to be limited to the embodiments shown but is to be accorded the widest scope consistent with the principles and features described herein.

FIG. 1 illustrates a conventional handheld system 100 that detects and compensates for unintentional muscle movements. The handheld system 100 includes a base 102, a gripping element 106 coupled to the base 102, and an object 116 (in this embodiment, a spoon) coupled to the gripping element 106. The base 102 houses a stabilizing assembly using shape memory alloy (SMA) wires 104, a power source 108 coupled to the stabilizing assembly 104, a single sensor 110 coupled to the power source 108, a controller 112 coupled to the single sensor 110, and a shaft 114 coupled to the stabilizing assembly 104. SMA wires are alloy wires that, after deformation, undergo a phase change to return to their original cold-forged shape after sufficient heat is applied. The SMA wires utilized in the stabilizing assembly 104 are heated by the power source 108 to trigger this phase change.

In the handheld system 100, the single sensor 110 is located within the base 102 to detect a user's motion and then the sensor 110 commands the stabilizing assembly using SMA wires 104 to produce a canceling motion. Unfortunately, several problems exist preventing the immediate use of SMA wires. For example, 5 SMA wires have not been proven for long-term, reliable use and also require significant complexity and cost to provide sufficient motion to cancel large amplitude (1-4 cm) disabling tremors.

In addition, because the single sensor 110 is located within the base 102, the use of the device is restricted to an object 116 that has a pre-determined length and 10 weight that must be pre-programmed into the controller 112. Deviations from this pre-determined length or weight will result in control instabilities and a reduction in the efficacy of the motion cancellation.

A system and method in accordance with the present invention addresses these drawbacks. The system and method include an inertial sensor placed along 15 an attachment arm and a motion-generating mechanism that does not utilize SMA wires. In so doing, the motion of the varying stabilized objects can be directly measured and there is no need for pre-programming the pre-determined lengths and weights into the controller. Additionally, a higher performing handheld form-factor solution is achieved and the size and cost of the active cancellation system is 20 further reduced. To describe the features of the present invention in more detail, refer now to the following description in conjunction with the accompanying Figures.

FIG. 2 illustrates a system 200 that detects and compensates for unintentional muscle movements in accordance with an embodiment. The system 200 includes a housing 202. The housing 202 includes a subsystem 204. The

system 200 also includes an attachment arm 206 coupled to the housing 202. At least one inertial sensor 208 is placed along the attachment arm 206. The attachment arm 206 is configured to accept an object 210 thereto. The subsystem 204 further includes a portable power source 212, a motion-generating mechanism 214, a controller 216, a control system 218, and at least one distributed motion sensor 220.

The attachment arm 206 can receive the object 210 in a variety of ways including but not limited to a friction, snap, or other form of locking mechanism. The portable power source 212 may utilize a variety of options including but not limited to a rechargeable battery and a solar panel. The operation and details of the elements of the at least one inertial sensor 208, at least one distributed motion sensor 220, motion-generating mechanism 214, controller 216, and control system 218 will be described in more detail hereinafter.

The at least one inertial sensor 208 and the at least one distributed motion sensor 220 detect unintentional muscle movements and measure signals related to these unintentional muscle movements that are created when a user adversely affects motion of the object 210. These sensors also detect the motion of the stabilized output relative to the housing 202. The control system 218 sends voltage commands in response to the measured signals to the motion-generating mechanism 214 through the controller 216 to cancel the user's tremors or unintentional muscle movements. This cancellation maintains and stabilizes a position of the object 210, keeping it centered relative to the housing 202.

The present invention may utilize various implementations of the controller 216, at least one inertial sensor 208, at least one distributed motion sensor 220, and

control system 218. In one embodiment, the controller 216 comprises an electrical system capable of producing an electrical response from sensor inputs such as a programmable microcontroller or a field-programmable gate array (FPGA). In one embodiment, the controller 216 comprises an 8-bit ATMEGA8A programmable
5 microcontroller manufactured by Atmel due to its overall low-cost, low-power consumption and ability to be utilized in high-volume applications.

In one embodiment, the at least one inertial sensor 208 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 220 is a contactless position
10 sensor including but not limited to a hall-effect magnetic sensor. In one embodiment, the control system 218 is a closed-loop control system.

The closed-loop control system senses motion and acceleration at various points in the system 200 and feeds detailed information into a control algorithm that moves the motion-generating mechanism 214 appropriately to cancel the net effect
15 of a user's unintentional muscle movements and thus stabilize the position of the object 210. The operation and details of the elements of the control system and control algorithm will be described in more detail hereinafter.

Also, one of ordinary skill in the art readily recognizes that a system and method in accordance with the present invention may utilize a variety of objects
20 including but not limited to kitchen utensils such as spoons and forks, grooming utensils such as make-up applicators, and various tools such as manufacturing, surgical and military tools. Thus, the system and method will 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 military applications.

The system 200 stabilizes the object 210's position about a neutral position (selected to be $\theta=0$) using the at least one inertial sensor 208. To achieve this, the position of the object 210 must be sensed along with the angle θ . For this position sensing, the at least one inertial sensor 208 is placed along the attachment arm 206 and is used to measure the absolute motion of the object 210 while providing low noise and sufficient sensitivity for the application. The direct sensor placement of the at least one inertial sensor 208 along the attachment arm 206 gives a unique advantage to the system 200 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 as the object 210 without the need to pre-determine and pre-program the length and weight of the object 210 into the controller 216.

The at least one distributed motion sensor 220 is located within the housing 202 which is located at the base of the system 200. The at least one distributed motion sensor 220 measures the relative motion of the attachment arm 206 relative to the housing 202, wherein the object 210 is kept at a center position relative to the housing 202. In one embodiment, the at least one distributed motion sensor 220 is at least one custom contactless hall-effect position sensor that provides angular feedback for the control system 218 and relies on a changing magnetic field that is dependent on the actuation angle.

The changing magnetic field is detected by a strategically placed integrated circuit (IC) located within the at least one distributed motion sensor 220, whose

analog output is read by the controller 216, providing a completely non-contact angular detection that is capable of withstanding a large number of cycles. The at least one distributed motion sensor 220, with its contactless sensing methods, provides significantly enhanced reliability over traditional direct-contact sensing methods such as potentiometers that wear over time.

Proper actuator operation is also a key to the overall operation of the system 200. Actuator options include SMA wires, piezoelectrics, linear voice-coils and coreless motors. However, SMA wires, piezoelectrics and linear voice-coils suffer from various fundamental problems. For example, as noted in the “Fatigue Life characterization of shape memory alloys undergoing thermomechanical cyclic loading” article within the “Smart Structures and Materials” publication, SMA wires suffer from reliability issues where failures occur after 10^4 to 10^5 cycles with strain amplitudes between 8.3% and 4.4%, which would amount to only 200 days usage time. Piezoelectrics, while capable of longer cycle times, are fragile and expensive. In addition, they require high operating voltages and thus require relatively large and expensive drive electronics. Linear voice-coils operate at lower voltages but suffer from low force outputs and high costs.

The present invention addresses these drawbacks by using a combination of coreless micro-motors and miniature gear-reduction systems coupled to the coreless micro-motors using a coupling mechanism for the motion-generating mechanism 214. In volume, coreless micro-motors are inexpensive and provide up to 1000 hours of operation time. 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 extremely low, estimated at 0.5 watts (W).

The coreless micro-motors are not only capable of holding a maximum load of 50 g while requiring 0.3 W of power, but are also capable of holding the lighter
5 average filled tablespoon load of 14 g while requiring a significantly lower 0.06 W of power. Thus, the coreless micro-motors are suitable in generating the required forces for the system 200.

FIG. 3 illustrates a motion-generating mechanism 300 in accordance with an embodiment. The motion-generating mechanism 300 is an embodiment of the
10 motion-generating mechanism 214 of the system 200. The motion-generating mechanism 300 includes a first miniature gear-reduction system coupled to a first coreless micro-motor 302 and a second miniature gear-reduction system coupled to a second coreless micro-motor 304. At least one inertial sensor 308 is placed along an attachment arm 306. The attachment arm 306 is configured to accept an object
15 310 thereto.

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)
20 direction. This motion from the second coreless micro-motor is supported by a vertical bearing.

A coupling mechanism is used to combine the horizontal and vertical motions of the two separate coreless micro-motor/miniature gear-reduction systems 302 and 304. This combination results in a bi-directional circular motion of the object 310 (in

this embodiment, a spoon). In one embodiment, the coupling mechanisms include but are not limited to sliding bearing mechanisms, gimbal structures, and bellows structures.

In the motion-generating mechanism 300, two degrees of freedom are generated from the two separate coreless micro-motor/miniature gear-reduction systems 302 and 304. Additional degrees of freedom (e.g., a third in the z-direction) can be added to the motion-generating mechanism 300 by adding motion to the output of the first coreless micro-motor or the output of the second coreless micro-motor.

To assist with the development of the control system type and parameter values, an analytical model of the system 200's properties was created. FIG. 4 illustrates an analytical model 400 in accordance with an embodiment. The analytical model 400 includes a handle 402, an actuator 404, an angular sensor 406, an attachment arm 408, an object 410, and an inertial sensor 412. The analytical model 400 was created with sufficient complexity to capture the dynamics of the system 200 and its response when synthesized with a closed-loop control system.

While the system 200 is designed to provide stabilization in multiple directions (e.g., vertical, horizontal, and the z-direction), analysis and modeling in only one direction is required because the motion outputs were symmetric and completely decoupled from one another. Thus, results from the vertical direction are directly applicable to other directions such as but not limited to the horizontal direction, assuming gravitational effects are negligible.

In the analytical model 400, the object 410 moves in the vertical y direction. The tremor disturbance or unintentional muscle movement (coordinate x) is assumed to act directly on the handle 402. The object 410 requiring stabilization (distance l from the base) moves a vertical distance y . This distance is related to the base coordinate x through the transformation,

$$y = x + l\theta, \quad (1)$$

where small angles are assumed. The actuator 404 is capable of moving the object 410 through the angle θ based on the controller's voltage output. The output torque of the actuator 404's coreless motor T is proportional to its armature current i through the relationship

$$T = K_t i, \quad (2)$$

where K_t is a constant. Similarly, the back electromotive force (emf), e is related to the coreless motor's rotational velocity through

$$e = K_e \dot{\theta}. \quad (3)$$

For simplicity, and based on the manufacturer's specifications, K_e and K_t are approximately equal and are therefore set to a constant k . With the actuator 404's model Equations 2 and 3, the system equations can be constructed through a combination of Newton's and Kirchhoff's laws. Through a moment balance the dynamic equation is constructed as

$$I \ddot{\theta} + \frac{m l}{2} \ddot{x} = k i. \quad (4)$$

The second system equation is constructed as

$$J \frac{di}{dt} + Ri = V - k \dot{\theta} \quad (5)$$

where V is the input voltage/command signal from the controller, J is the inductance of the actuator 404, and R is the internal resistance of the actuator 404.

The system 200 acts as a low-pass filter because it is designed to cancel high-frequency tremor disturbances/unintentional muscle movements while retaining low-frequency intended motions. Thus, the system 200 can be modeled as a transfer function, where an input amplitude X (tremor disturbance) is entered into the system 200, and an output Y (motion of the stabilized object) is observed and controlled.

For further analysis on tremor cancellation and to assist in controller design, the system Equations 4 and 5 were transformed into the frequency domain and manipulated to produce the desired transfer function. Using the coordinate transformation Equation 1 and performing a Laplace transform, Equations 4 and 5 were modified to produce

$$\frac{I}{l}s^2(Y(s) - X(s)) + \frac{ml}{2}s^2X(s) = kI(s) \quad (6)$$

and

$$JsI(s) + RI(s) = V - \frac{Ks}{l}(Y(s) - X(s)) \quad (7)$$

Solving Equation 7 for $I(s)$ and substituting the result into Equation 6 produces a single equation

$$\frac{I}{l}s^2(Y(s) - X(s)) + \frac{ml}{2}s^2X(s) = k \left(\frac{V - \frac{Ks}{l}(Y(s) - X(s))}{Js + R} \right) \quad (8)$$

The remaining input in Equation 8 is V , which is the input voltage/command signal from the controller. This signal was designed to be simple in nature to minimize

computational requirements and thus significantly reduce the cost and power consumption of the necessary microcontroller.

FIG. 5 illustrates a system diagram 500 of the control system 218 in accordance with an embodiment. The system diagram 500 includes an unintentional muscle movement 502, a stabilized object 504, acceleration signals 506, an adaptive acceleration set-point 508, a position set-point 510, a control algorithm 512, a voltage command output 514, a motion-generating mechanism 516, and position signals 518.

An unintentional muscle movement 502 by a user that adversely affects the motion of the stabilized object 504 is detected. Position signals 518 relative to the housing are measured by the at least one contactless position angular sensor and then are compared to the position set-point 510 that is stored in the microcontroller's memory (e.g., Electrically Erasable Programmable Read-Only Memory (EEPROM)). The position set-point 510 is the neutral position of the stabilized object 504 and is initially calibrated when the system 200 is first activated. This comparison results in a first input signal.

Acceleration signals 506 are measured by the at least one inertial sensor and then are compared to an adaptive acceleration set-point 508. The adaptive acceleration set-point 508 removes the effects of slow changes in the gravity field due to the changing orientation of the device. The adaptive acceleration set-point 508 can be implemented through the use of a median filter, low-pass filter, or other digital/analog filter capable of removing low frequencies from a signal. This comparison results in a second input signal.

The control algorithm 512 processes the first and second input signals and sends an appropriate voltage command output 514 to the motion-generating mechanism 516 in each controlled direction to actively cancel the user's unintentional muscle movement and maintain the stabilized object 504.

5 Based on these two input signals (acceleration signal and angle θ), a control law must be constructed for the control algorithm 512. One of ordinary skill in the art readily recognizes that a system and method in accordance with the present invention may utilize a variety of different control laws that provide tremor disturbance cancellation while ensuring stability of the object and that would be
10 within the spirit and scope of the present invention.

For example, a control law can be derived by applying proportional and derivative gains to the angle θ along with the acceleration signal resulting in

$$V = K_1\theta - K_2\ddot{y} + K_3\dot{\theta} \quad (9)$$

15 In this example, the feedback on the acceleration term provides the desired low-pass filtering properties. In the exemplified control law (Equation 9), the proportional feedback on the angle θ is applied to allow the device to mimic the function of conventional implements. This is achieved by creating "stiffness" in the angular direction to allow the device to support various loads and while remaining in
20 the neutral position during the inactive state. Derivative control on the angular input was selected for stability, particularly to dampen any resonances introduced by the proportional feedback on θ . The exemplified control law is both effective and computationally simple.

This allows the control algorithm 512 to be implemented in the highly
25 compact, low-power, and low-cost microcontrollers of the system 200. Substituting

the exemplified control law (Equation 9) into V in Equation 8 and expanding the terms allows Equation 8 to be expressed as the following transfer function

$$\frac{Y(s)}{X(s)} = \frac{n}{d} \quad (10)$$

5 where the numerator is

$$n = (2ILJ^2 - mL^3J^2)s^4 + (4ILJR - 2mL^3JR)s^3 + (2K^2LJ + 2K_3KLJ - mL^3R + 2ILR^2)s^2 + (2K^2LR + 2K_1KLJ + 2K_3KLR)s + 2K_1KLR \quad (11)$$

10 and the denominator is

$$d = (2ILJ^2)s^4 + (2K_2KL^2J + 4ILJR)s^3 + (2K^2LJ + 2K_2KL^2R + 2K_3KLJ + 2ILR^2)s^2 + (2K^2LR + 2K_1KLJ + 2K_3KLR)s + 2K_1KLR \quad (12)$$

15 To reject unintentional muscle movements while retaining intended motions, the parameters of the exemplified control law (Equation 9) are optimized through numerical simulation. For example, this optimization minimizes the average displacement magnitude of the stabilized object 504 (Y , Equation 10) over the unintentional muscle movement frequency range of 3-7 Hz, while varying the
20 controller gains K_1 , K_2 , K_3 . Further, in this example, the constraints are defined such that low-frequency motions in the intended motion frequency range of 0-1 Hz are unaffected and stability is mathematically ensured. The average phase lag is also constrained to be less than 15 degrees from 0-1 Hz, which is assumed to be unnoticeable to the user.

25 For the optimization, computational functions are written to interact with the trust-region reflective optimization algorithm *fmincon* in Matlab. The algorithm is run to provide a final solution, $K=[121,366,154]$, which is used for the controller 216 in the system 200. The function has a minimum value of 0.15, which means that the

system 200 is capable of filtering on average 80% of the input tremor disturbances/unintentional muscle movements in the frequency range of 3-7 Hz.

Additional sensing and processing schemes can be utilized to obtain active cancellation of the unintentional muscle movements. FIG. 6 illustrates a non-
5 contact sensing system 600 in accordance with an embodiment. The non-contact sensing system 600 includes a stabilization unit 602 that comprises a stabilized implement portion 602a and a base portion 602b. The at least one non-contact position sensor 604 detects position data of the stabilization unit 602 and transmits the position data to the processing unit 606 which determines proper control
10 mechanisms to cancel out the unintentional muscle movements. The proper control mechanisms are transmitted back to the stabilization unit 602 via a wireless link 608. In one embodiment, the transmission occurs via a wired link between the processing unit 606 and the stabilization unit 602.

The at least one non-contact position sensor 604 detects the position of
15 multiple points along both the stabilized implement portion 602a and the base portion 602b in a three-dimensional coordinate system (e.g. x, y, and z coordinates). In one embodiment, the at least one non-contact position sensor 604 is an optical camera such as any of an infrared (IR) camera, a visible light camera, and a stereo camera. In another embodiment, the at least one non-contact position
20 sensor 604 is any of a laser displacement sensor, an ultrasonic sensor.

In FIG. 6, position data of the stabilization unit 602 is extracted from the non-contact position sensor 604 and transmitted to the processing unit 606. In one embodiment, the processing unit 606 comprises a microprocessor that is capable of running and processing control algorithms associated with analyzing the received

position data. In another embodiment, the processing unit 606 is any of a personal computer device, a mobile phone, and a custom signal processor. After receiving the position data and processing control algorithms, the processing unit 606 transmits actuator commands via the wireless link 608 to the base portion 602b of the stabilization unit 602.

In one embodiment, the base portion 602b includes embedded sensors including but not limited to accelerometers and gyro sensors for feedback control and the cancellation of unintentional muscle movements. In another embodiment, the base portion 602b switches from utilizing data detected from the embedded sensors to utilizing data detected from the at least one non-contact position sensor 604 when available. In another embodiment, the base portion 602b combines data detected from the embedded sensors and the at least one non-contact position sensor 604 to optimize the cancellation of unintentional muscle movements.

Referring to FIG. 6 and FIG. 7 together, FIG. 7 illustrates a flowchart of a signal processing algorithm 700 processed by the processing unit 606 of the non-contact sensing scheme in accordance with an embodiment. The signal processing algorithm 700 receives position data of the stabilized object that has been detected by a non-contact position sensor, via step 702, and filters the position data to identify tremor and unintentional muscle movements, via step 704. The signal processing algorithm further models the identified tremor, via step 706, and produces motor commands that will cancel out the identified tremor, via step 708.

In FIG. 7, the signal processing algorithm 700 is utilized by the processing unit 606 to detect position data of both the stabilized implement portion 602a and the base portion 602b of the stabilization unit 602 and extract the

unwanted/unintentional tremor. In one embodiment, the processing unit 606 utilizes any of low pass filters, weighted-frequency Fourier linear combiners, and notch filters to extract the unwanted tremor. A system model is employed to calculate motor commands necessary to cancel the motion of the unwanted tremor and the
5 motor commands are transmitted via either a wireless or wired link to the stabilization unit 602. The remote, wireless sensing, processing, and controlling makes the non-contact sensing scheme compact and flexible for a variety of applications.

As above described, the system and method in accordance with the present
10 invention allow for a highly compact active cancellation approach that seeks to accommodate a user's tremor by allowing it to exist while cancelling its effects and stabilizing the position of the object. By implementing a motion-generating mechanism to provide the necessary forces and displacements for tremor cancellation and a control system and sensor topology to control this motion-
15 generating mechanism, the system and method in accordance with the present invention achieve a more robust handheld form-factor with a significantly reduced size and cost.

Although the present invention has been described in accordance with the embodiments shown, one of ordinary skill in the art will readily recognize that there
20 could be variations to the embodiments and those variations would be within the spirit and scope of the present invention. Accordingly, many modifications may be made by one of ordinary skill in the art without departing from the spirit and scope of the appended claims.

CLAIMS

What is claimed is:

1. A non-contact sensing system, comprising:
a stabilization unit;
5 at least one non-contact position sensor coupled to the stabilization unit;
and a processing unit coupled to the at least one non-contact position sensor, wherein the processing unit transmits motion commands to the stabilization unit to cancel unintentional muscle movements.
- 10 2. The non-contact sensing system of claim 1, wherein the stabilization unit includes an implement portion and a base portion.
3. The non-contact sensing system of claim 2, wherein the implement portion includes an attachment arm and a first sensor coupled to the attachment arm,
15 wherein the base portion includes a power source, a motion-generating mechanism coupled to the power source, a controller coupled to the motion-generating mechanism, a control system coupled to the controller, and a second sensor coupled to the control system.
- 20 4. The non-contact sensing system of claim 1, wherein the at least one non-contact position sensor is any of an infrared (IR) optical camera, a visible light camera, a stereo camera, a laser displacement sensor, and an ultrasonic sensor.
5. The non-contact sensor system of claim 1, wherein the at least one non-
25 contact position sensor detects position data associated with the stabilized unit.
6. The non-contact sensor system of claim 5, wherein the processing unit receives the position data from the at least one non-contact position sensor and calculates the motion commands based upon the position data.

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7. The non-contact sensor system of claim 6, wherein the processing unit calculates the motion commands utilizing a signal processing algorithm.

8. The non-contact sensor system of claim 7, wherein the signal processing algorithm is developed utilizing any of low pass filters, weighted-frequency Fourier linear combiners, and notch filters.

9. The non-contact sensor system of claim 7, wherein the signal processing algorithm further comprises position data filtration, tremor identification, system modeling, and actuator command generation.

10. The non-contact sensor system of claim 2, wherein the base portion of the stabilization unit switches between utilizing embedded sensor data and position data detected by the at least one non-contact position sensor.

11. The non-contact sensor system of claim 1, wherein the stabilization unit comprises:

a housing, wherein the housing includes a subsystem that comprises a power source, a motion-generating mechanism coupled to the power source, a controller coupled to the motion-generating mechanism, a control system coupled to the controller, and at least one first sensor coupled to the control system; and

an attachment arm coupled to the housing, wherein at least one second sensor is placed along the attachment arm, wherein the attachment arm is configured to receive an object, wherein in response to an unintentional muscle movement by a user that adversely affects motion of the object, the subsystem stabilizes a position of the object.

12. A method for cancelling unintentional muscle movements using non-contact sensing, the method comprising:

receiving position data of a stabilization unit that is detected by at least one non-contact position sensor;

filtering the position data to identify the unintentional muscle movements;

modeling the position data to create a system model; and
determining motor commands based upon the system model to cancel the
unintentional muscle movements.

5 13. The method of claim 12, wherein the stabilization unit includes an implement
portion and a base portion, further wherein the implement portion includes an
attachment arm and a first sensor coupled to the attachment arm, wherein the base
portion includes a power source, a motion-generating mechanism coupled to the
power source, a controller coupled to the motion-generating mechanism, a control
10 system coupled to the controller, and a second sensor coupled to the control
system.

14. The method of claim 12, wherein the receiving further comprises:
receiving position data of the stabilization unit in x, y, and z coordinates that
15 is detected by any of an infrared (IR) optical camera, a visible light camera, a stereo
camera, a laser displacement sensor, and an ultrasonic sensor.

15. The method of claim 12, wherein the filtering further comprises:
filtering the position data using a low pass filter to identify the unintentional
20 muscle movements.

16. The method of claim 12, wherein the determining further comprises:
determining the motor commands using a signal processing algorithm and
the system model to cancel the unintentional muscle movements.

25 17. The method of claim 16, wherein the signal processing algorithm is
developed utilizing any of low pass filters, weighted-frequency Fourier linear
combiners, and notch filters.

30 18. The method of claim 12, further comprising:
transmitting the motor commands to the stabilization unit via any of a
wireless and wired connection.

19. A non-contact sensing system, comprising:

a stabilization unit;

at least one non-contact position sensor coupled to the stabilization unit; and

5 a processing unit in communication with the stabilization unit via a wireless link, wherein the processing unit is further coupled to the at least one non-contact position sensor and transmits motion commands to the stabilization unit via the wireless link to cancel unintentional muscle movements.

10 20. The non-contact sensor system of claim 19, wherein the stabilization unit comprises:

a housing, wherein the housing includes a subsystem that comprises a power source, a motion-generating mechanism coupled to the power source, a controller coupled to the motion-generating mechanism, a control system coupled to
15 the controller, and at least one first sensor coupled to the control system; and

an attachment arm coupled to the housing, wherein at least one second sensor is placed along the attachment arm, wherein the attachment arm is configured to receive an object, wherein in response to an unintentional muscle movement by a user that adversely affects motion of the object, the subsystem
20 stabilizes a position of the object.

25

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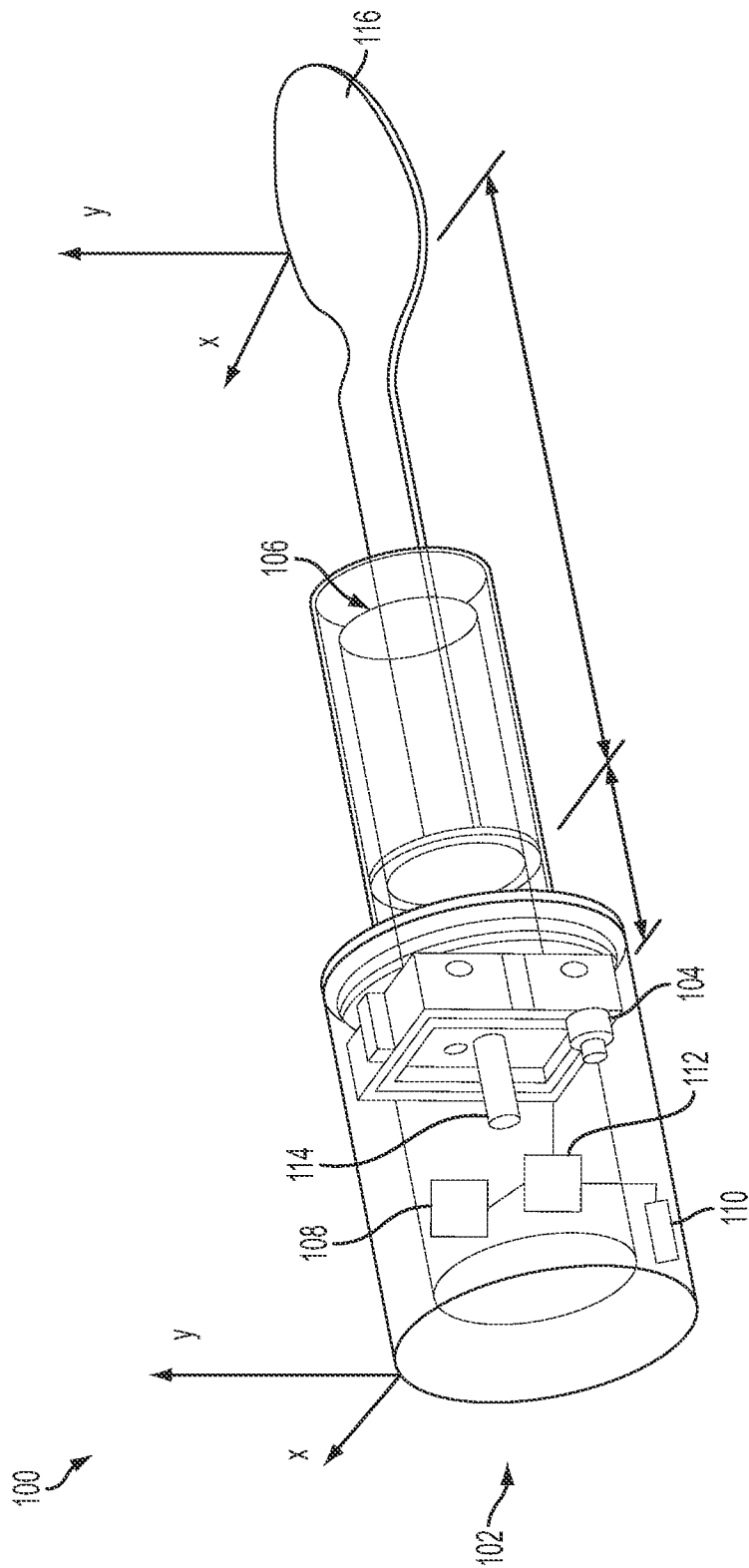


FIG. 1

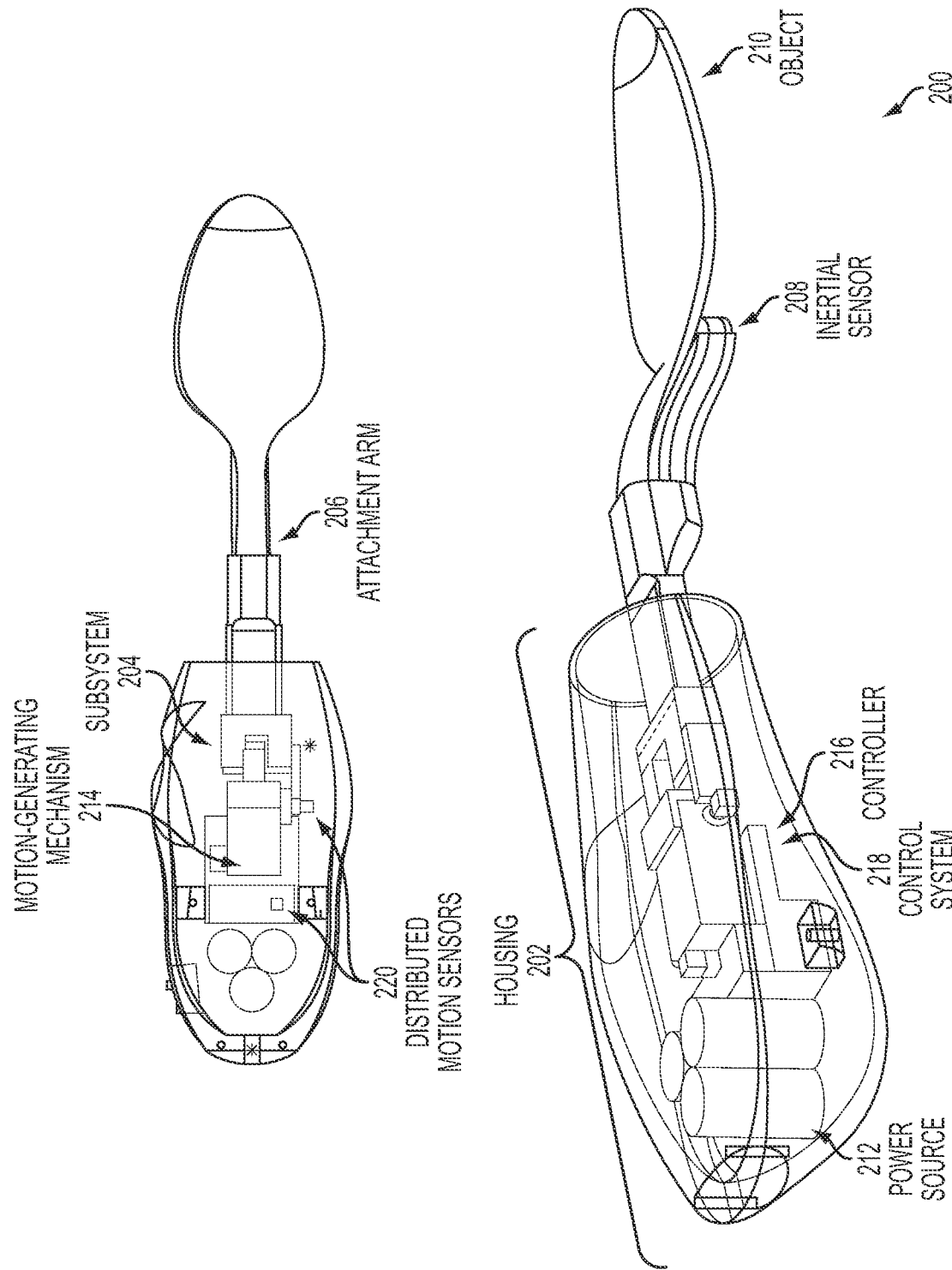


FIG. 2

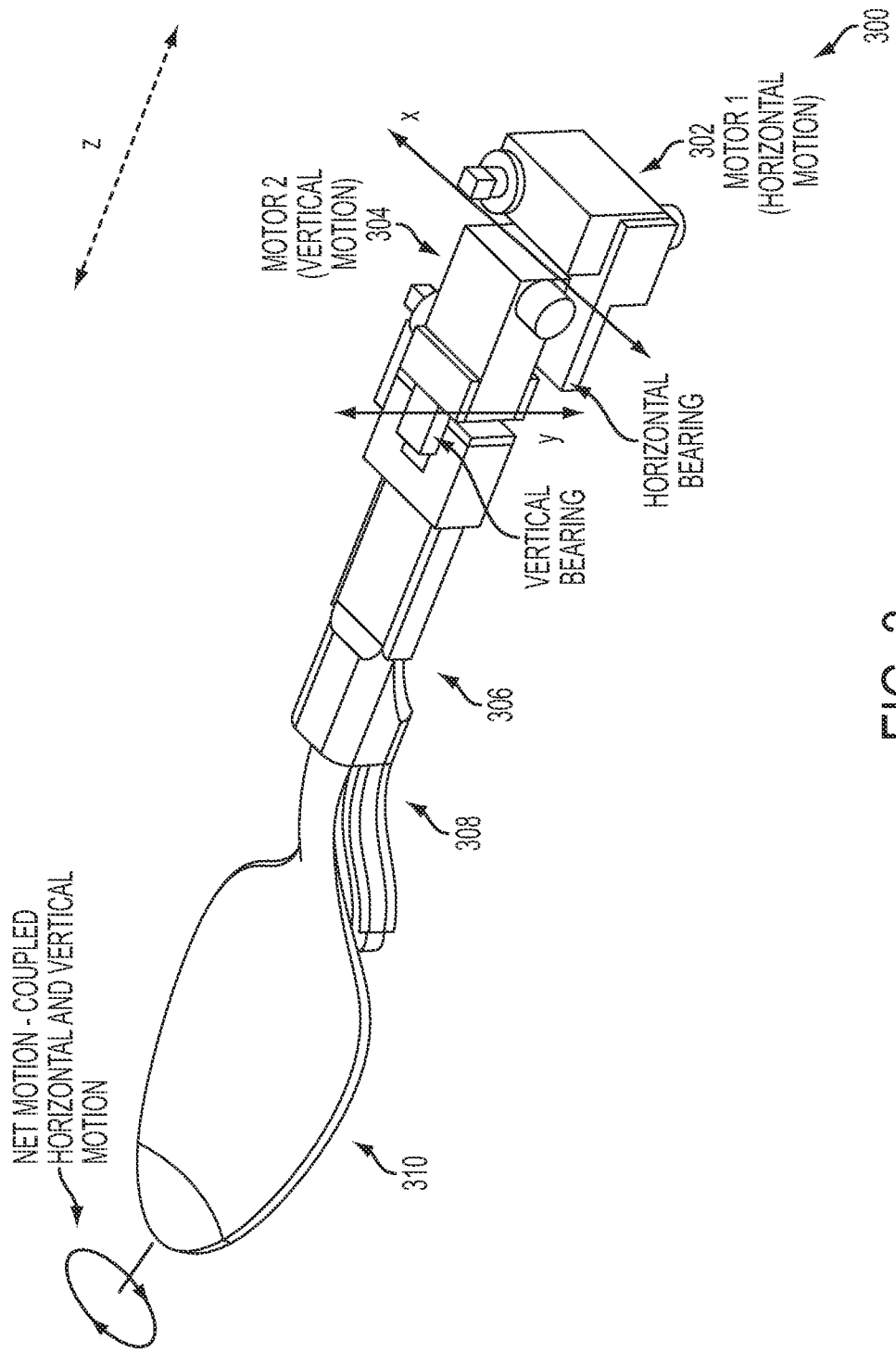


FIG. 3

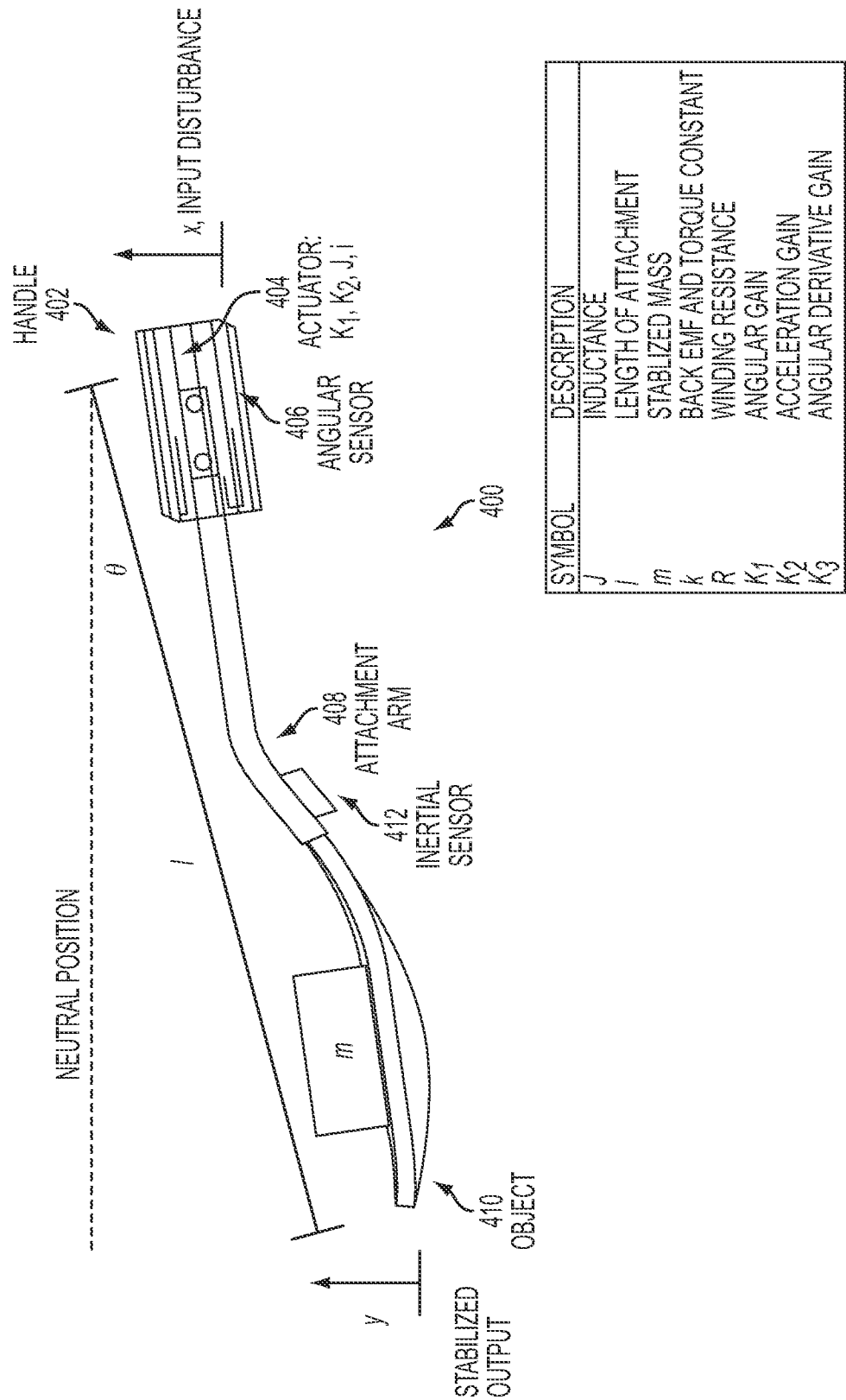


FIG. 4

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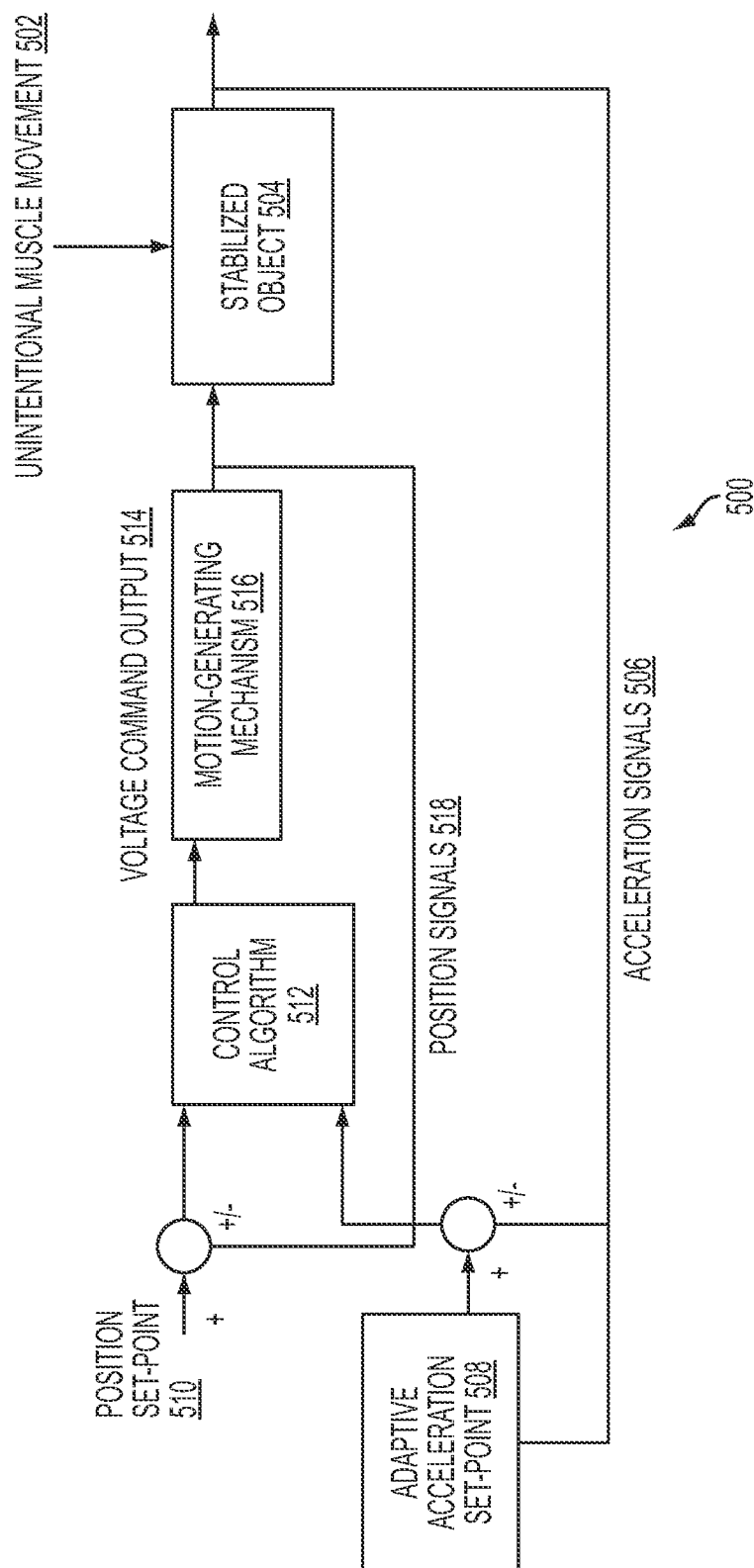


FIG. 5

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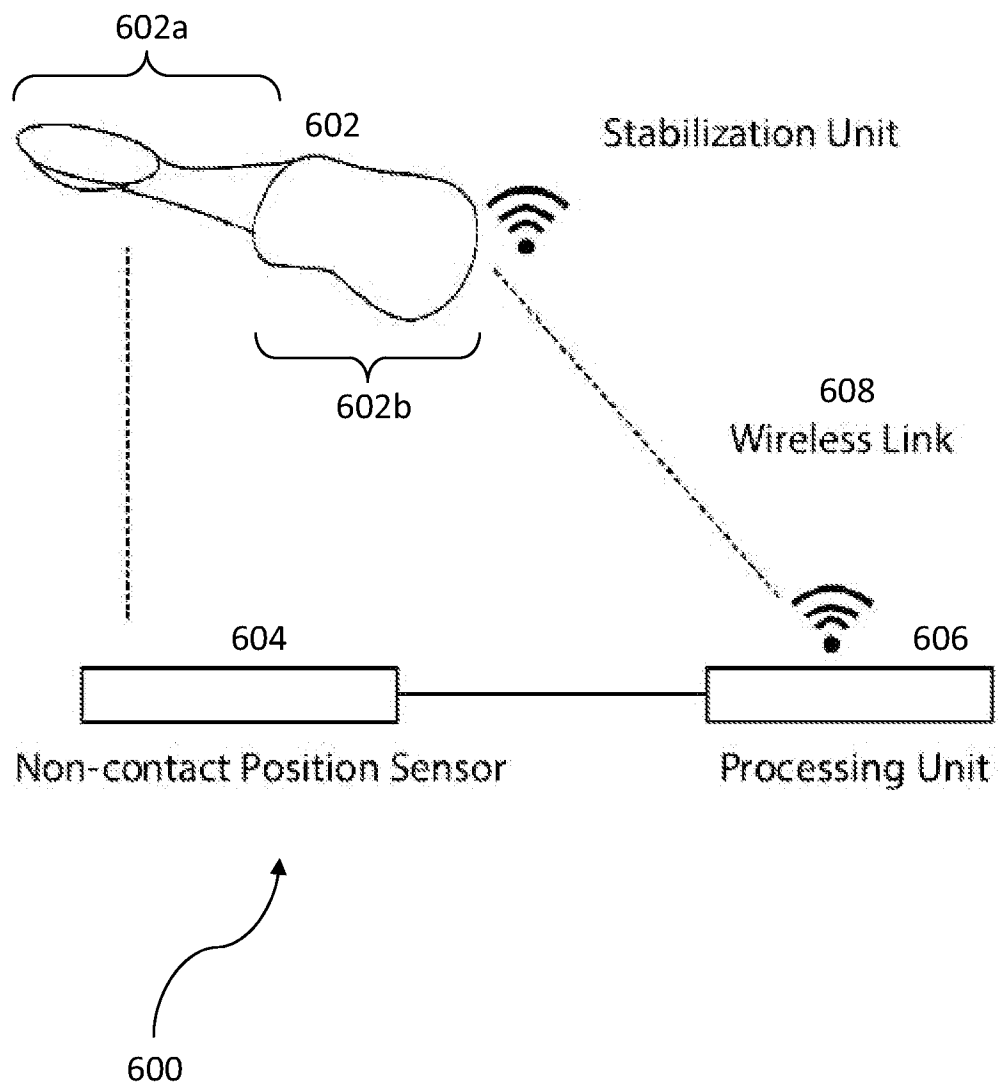


FIG. 6

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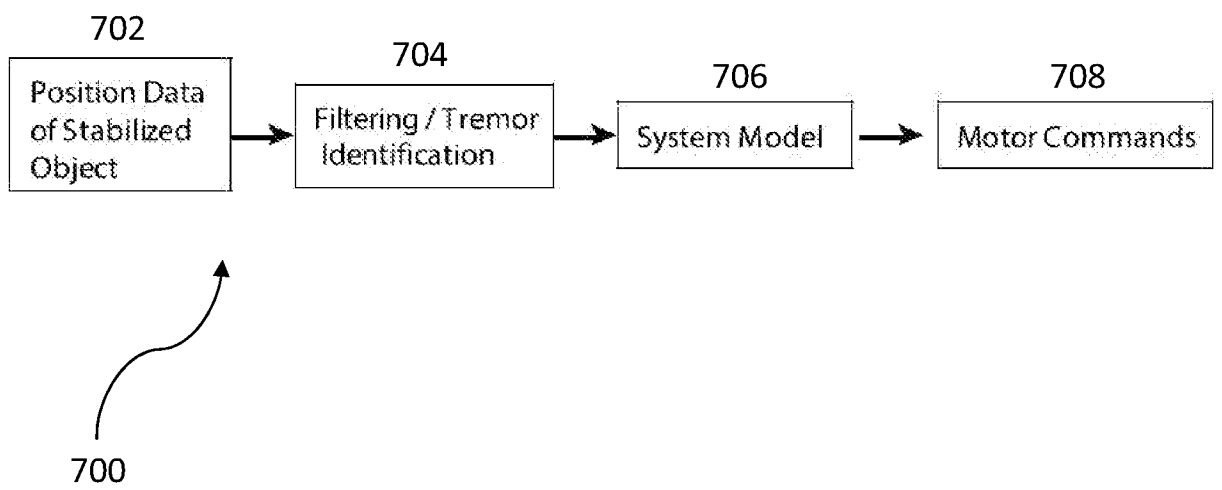


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/045409

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61B 5/11 (2014.01)

CPC - A61B 5/1101 (2014.09)

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)

IPC(8) - A61B 5/00, 11; 6/00 (2014.01)

USPC - 600/595

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - A61B 5/0002, 0004, 0059, 11, 1101, 1107, 1121 (2014.09)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7,883,479 B1 (STANLEY et al.) 08 February 2011 (08.02.2011) entire document	1-20
Y	US 2009/0173351 A1 (SAHIN et al.) 09 July 2009 (09.07.2009) entire document	1-20
A	US 2010/0130873 A1 (YUEN et al.) 27 May 2010 (27.05.2010) entire document	1-20
A	US 2003/0209678 A1 (PEASE) 13 November 2003 (13.11.2003) entire document	1-20

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

16 October 2014

Date of mailing of the international search report

03 NOV 2014

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