TITLE

METHOD AND SYSTEM FOR POSTURAL STABILITY ASSESSMENT

CROSS-REFERENCE TO RELATED APPLICATIONS AND PRIORITY

[0001] The present application claims priority to Indian complete specification (Title: METHOD AND SYSTEM FOR POSTURAL STABILITY ASSESSMENT) Application No. (201721024012), filed in India on July 7th, 2017.

TECHNICAL FIELD

[0002] The disclosure herein generally relate to health monitoring and assessment systems, and, more particularly, to perform postural stability assessment of a user and quantify the assessed postural stability.

BACKGROUND

[0003] Postural instability is one of the prominent symptom associated with geriatric population and in many patients with neurological disorders like Stroke, Dementia, Parkinson's disease (PD), etc. Postural instability is also the major precursor of fall and about 35% of geriatric population fall each year, making fall prediction a significantly impacting parameter for geriatric health monitoring. Post stroke rehabilitation treatment reveals that about 83% of stroke patients suffers from postural instability leading to high fall risk.

[0004] Measurement or quantification of stability is required to estimate severity of stroke, define treatment plan and monitoring progress of rehabilitation programs. Postural instability is one of the cardinal signs of PD. The instability leads to progressive reduction in both static and dynamic balance, resulting in recurrent falls.

[0005] In view of the problems associated with postural instability and fall in a large population with neurological disorder and the total

geriatric population, many postural stability assessment systems have been introduced to the market. Most of these postural stability assessment systems are capable of performing the postural stability, however, require manual intervention at different stages of the assessment. Further, the existing systems require service of a trained person to operate the systems and a medically qualified person to interpret outputs. Further, the existing systems in the area of stability assessment work in a static manner by providing a pre-defined questionnaire to the user and by collecting and analyzing user response to the questionnaire.

SUMMARY

[0006] Embodiments of the present disclosure present technological improvements as solutions to one or more of the above-mentioned technical problems recognized by the inventors in conventional systems. For example, in one embodiment, a postural stability assessment system is provided. The system includes a processor; and a memory module comprising a plurality of instructions, the plurality of instructions configured to cause the processor to monitor an action being performed by a user and collecting at least one input pertaining to the action being performed by the user, by an Input/Output (I/O) module of the postural stability assessment system. Further, a SLS duration measurement module of the postural stability assessment system determines a value corresponding to Single Limb Stance (SLS) duration of the user, based on the at least one input. A body joint vibration determination module of the postural stability assessment system then determines a value corresponding to body joint vibration of the user, based on the at least one input. Further, a sway area determination module of the postural stability assessment system determines a value corresponding to body sway area of the user, based on the at least one

input. A stability index generation module of the postural stability assessment system then determines the SLS duration, the body joint vibration, and the body sway area, of the user as falling under at least one respective category, and further generates a postural stability index score for the user, based on the determined at least one category of the SLS duration, the body joint vibration, and the body sway area. A stability assessment module of the postural stability assessment system then assesses postural stability of the user, based on the postural stability index score.

[0007] In another aspect, a processor-implemented method for postural stability assessment of a user is provided. In this method, in order to perform the postural stability assessment, initially at least one input pertaining to a Single Limb Stance (SLS) duration, body joint vibration, and body sway area, of a user being monitored for postural stability assessment, are collected, via one or more hardware processors, by a postural stability assessment system. Further, the postural stability assessment system determines the SLS duration, the body joint vibration, and the body sway area, of the user as falling under at least one respective category, via the one or more hardware processors. Further, a postural stability index score is generated for the user, based on the determined at least one category of the SLS duration, the body joint vibration, and the body sway area, via the one or more hardware processors, by the postural stability assessment system. Further, postural stability of the user is assessed based on the postural stability index score, by the postural stability assessment system.

[0008] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles:

[0010] FIG. 1 illustrates a block diagram of a postural stability assessment system for performing postural stability assessment of a user, according to some embodiments of the present disclosure.

[0011] FIG. 2 is a flow diagram depicting steps involved in the process of performing postural stability assessment, using the postural stability assessment system, according to some embodiments of the present disclosure.

[0012] FIG. 3 is a flow diagram depicting steps involved in the process of identifying membership function for SLS duration, body joint vibrations, and body sway area of a user being monitored, using the postural stability assessment system, according to some embodiments of the present disclosure.

[0013] FIG. 4 is a flow diagram depicting steps involved in the process of dynamically determining range of membership functions of SLS duration, body joint vibrations, and body sway area of a user, using the postural stability assessment system, according to some embodiments of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] Exemplary embodiments are described with reference to the accompanying drawings. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the spirit and scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims.

[0015] Referring now to the drawings, and more particularly to FIG. 1 through 4, where similar reference characters denote corresponding features consistently throughout the figures, there are shown preferred embodiments and these embodiments are described in the context of the following exemplary system and/or method.

[0016] FIG. 1 illustrates a block diagram of a postural stability assessment system for performing postural stability assessment of a user, according to some embodiments of the present disclosure. The postural stability assessment system 100 includes an Input/Output (I/O) module 101, a Single Limb Stance (SLS) duration measurement module 102, a body joint vibration measurement module 103, a sway area determination module 104, a stability index generation module 105, and a stability assessment module 106.

[0017] The I/O module 101 is configured to provide at least a channel with appropriate communication protocol support, for facilitating communication between the postural stability assessment system 100 and at least one external entity. The 'external entity' herein can be a user or an external system. For example, using a suitable interface provided by

the I/O module 101, one or more users may interact with the postural stability assessment system 100. In another example, an external system can connect and communicate with the postural stability assessment system 100, for data transfer and/or any such action. The I/O module 101 can be further configured to provide suitable communication channel for communication between the components of the postural stability assessment system 100. The I/O module 101 is further configured to provide suitable options for monitoring action(s) being performed by one or more users, and collect one or more inputs with respect to one or more actions being performed by the user. The I/O module 101 is further configured to collect one or more inputs required for the postural stability assessment, by monitoring the user. For example, the I/O module 101 can use a Kinect® system that is internally or externally associated (or connected) with the postural stability assessment system 100, so as to monitor user action(s) and collect the required input(s). For example, for the purpose of postural stability data assessment, the I/O module 101 can be configured to monitor and record spatio-temporal information of twenty five joints of each user being monitored. The I/O module 101 can be further configured to perform necessary pre-processing of the data collected as input, so as to condition the data for further processing, wherein conditioning of the data refers to preparing the data suitable for further processing (for example, by performing actions such as but not limited to removal of noise content, conversion of the data to appropriate format and so on).

[0018] The SLS measurement module 102 is configured to collect the user specific input data from the I/O module 101, process the collected data, and determine SLS time duration for the user. Here, the SLS time duration indicates the time period for which the user being monitored performed the action(s) as required by standard SLS test. For example, SLS time duration is determined by monitoring variation in lifted leg's ankle coordinates. For example, when Kinect® is used for monitoring

and data collection, skeleton joints obtained from Kinect® are represented by 3D world co-ordinates (x, y, z) where 'x' represents left/right variation, 'y' represents up/down variation w.r.t ground and 'z' represents to/from variation of subject w.r.t Kinect®. Changes in the lifted leg's ankle y-co-ordinate (say, left leg is lifted) 'YAnkleLeft' can give meaningful information about the precise timing when a subject lifts leg (here, left-leg) above the ground. Similarly right leg's movement also can be tracked.

[0019] The body joint vibration determination module 103 is configured to collect the user specific input data collected by the I/O module 101, process the collected data, and determine values that represent one or more types of body joint vibrations while the user was performing one or more specific actions as required for the postural stability assessment. For example, while the user is standing on single limb as part of SLS exercise, the user oscillates in order to maintain the balance. Body joint, especially hip joint contributes maximally to correct the effect of instability to maintain the posture. Acceleration of hip joint center in x, y, z direction is analyzed for estimating body joint vibration. Mean frequencies of the hip joint center were calculated using appropriate techniques such as Fourier transform and the relative frequency variation between each segments of SLS (i.e., double stance, single stance followed by double stance), gives a vibration index.

[0020] The sway area determination module 104 is configured to assess body sway from the collected input data, and determine sway of Center of Mass (CoM). Any suitable technique (for example, Statically Equivalent Serial Chain (SESC)) can be used by the sway area determination module 104 for determining the CoM. SESC model locates the CoM of any linkage by means of a serial chain and the links in the chain are defined by their geometric configuration and mass distribution. Shoulder center and hip center are considered as the start and end point of the serial chain respectively. Midpoint of this chain is estimated to be the body CoM, and projection of the estimated CoM is equivalent to body

sway. The sway area can be calculated using any suitable algorithm. For example, a convex hull algorithm can be used. In the convex hull method triangulation of the point sets is calculated first. The points of interest are the x and z coordinates of estimated CoM. These coordinates (x1; z1) :::(xn; Zn) of the polygon are arranged in a determinant, and cross product of the determinant generates the sway area.

[0021] The stability index generation module 105 is configured to collect information pertaining to the determined SLS time duration, body joint vibration, and sway area, and process them together to generate a postural stability index score, wherein the postural stability index score represents level of postural stability of the user, and can further indicate any potential health risks. The stability index generation module 105 processes information pertaining to the SLS time duration, body joint vibration, and sway area, based on certain pre-defined rules. During this process, the stability index generation module 105 compares determined values of the SLS time duration, body joint vibration, and sway area with corresponding membership function ranges, and accordingly determines one membership function each that suits the determined value of each parameter. Here, 'membership function' refers to of classifications each of SLS time duration, body joint vibration, and sway area under different categories (wherein each category is defined in terms of range of values). Given below is an example classification:

SLS duration: Poor: 8 to 25 sec, Avearge: 20 to 40 sec, Good: 35 – 85 sec, Excellent: 80 to 120 sec.

Body (Hip) Joint vibration: Poor: 0 to 5, Average: 5 to 15, Good: 15 to 35, Excellent: 30 to 50.

CoM sway area: Poor: 16 to 25; Average: 8 to 16; Good: 4to 8; Excellent: 0 to 4.

[0022] In an embodiment, the stability index generation module 105 dynamically determines the ranges for a person being analyzed. The stability index generation module 105 may consider the parameters such

as but not limited to age of the user, geographical location of the user and so on, that has impact on physical health of a user, in order to dynamically determine the ranges, and compare values corresponding to such features with a learning model that specifies criteria for selecting the ranges. By comparing the value of each parameter with corresponding membership function ranges, the stability index generation module 105 determines the matching membership functions for the user. The means, each of SLS duration, body joint vibration, and sway area is classified as one of GOOD, BAD, AVERAGE, EXCELLENT. In another embodiment, the stability index generation module 105 dynamically determines the range of membership functions for a user, based on one or more diseases the user has. For example, ranges of membership functions for all users suffering from stroke. Similarly, for all users suffering from another particular disease, the range would be a different set of values. In this scenario, information pertaining to one or more diseases a user is suffering from, is collected as one of the inputs, by the stability index generation module 105, through the I/O module 101, for the purpose of determining the range of membership functions for the user. Similarly Neurological balance disorders like stroke, dementia etc., musculoskeletal balance disorders like arthritis and geriatric care These membership functions are then combined with rules to generate the postural stability score. In an embodiment, any suitable technique (for example, Fuzzy logic) can be used to combine the membership functions and the rules. A few examples of the rules used are:

- Rule 1: IF SLS duration is EXCELLENT; AND vibration index is GOOD; AND sway area is GOOD; THEN stability is EXCELLENT (score-75 to 100)

- Rule 2: IF SLS duration is Good; AND vibration index is Average; AND sway area is GOOD; THEN stability is Good (score-50 to 75)

- Rule 3: IF SLS duration is AVERAGE; AND vibration index is GOOD; AND sway area is AVERAGE; THEN stability is AVERAGE (score-25 to 50)

- Rule 4: IF SLS duration is POOR; AND vibration index is POOR; AND sway area is AVERAGE; THEN stability is POOR (score-0 to 25)

[0023] Using the combination of membership functions and the rule, the postural stability index score for the user is determined. Value of the postural stability index score, as determined, is then provided as input to the stability assessment module 106. The stability assessment module 106 can be configured to interpret the postural stability index score received as input, and generate appropriate suggestions/recommendations which are then provided as output to the user. In an embodiment, the interpretation of the postural stability index score is performed by the stability assessment module 106, on the basis of information that is statically or dynamically configured. For example, if the value of the postural stability index score is 20, then the stability is POOR, and the user may be recommended appropriate medical checkup and the like.

[0024] The memory module 107 can be configured to store any data that is associated with the postural stability assessment. In an embodiment, the information pertaining to membership functions of different parameters for a user or for a particular population, statically or dynamically decided, is stored in the memory module 107. Similarly all rules that are to be used for performing the postural stability assessment also are stored in the memory module 107. Further, all information (inputs, outputs and so on) pertaining to postural stability assessment performed for each user may also be stored in the database, as history data, for reference purpose. The learning model also is stored in the

memory module 107. The memory module 107 may be volatile or non-volatile, as per requirements.

[0025] FIG. 2 is a flow diagram depicting steps involved in the process of performing postural stability assessment, using the postural stability assessment system, according to some embodiments of the present disclosure. By monitoring a user for whom the posture stability assessment is to be performed, while the user is performing specific (manual) actions that are required for the postural stability assessment (SLS test for instance) required inputs are collected which can be further used for the assessment.

[0026] The input(s) thus collected is then processed by the postural stability assessment system 100 to determine (202) values that represent SLS duration, body joint vibration, and body sway area, for the user. The identified values are further processed by the postural stability assessment system 100 to identify (204) these values as belonging to (or matching) specific membership functions. The postural stability assessment system 100 further generates (206) a postural stability index score for the user, based on the identified membership functions and at least one rule. The postural stability assessment system 100 further assesses postural stability of the user, based on the generated postural stability index score. Various actions in Fig. 2 can be performed in the same order or in a different order. Further, or one or more of the actions in method 200 can be omitted.

[0027] FIG. 3 is a flow diagram depicting steps involved in the process of identifying membership function for SLS duration, body joint vibrations, and body sway area of a user being monitored, using the postural stability assessment system, according to some embodiments of the present disclosure. The postural stability assessment system 100 determines values of SLS duration, body joint vibration, and CoM of body sway area (302, 306, and 310 respectively), by processing the real-time inputs collected (301) by monitoring the user. The values thus determined

are then compared (304, 308, 312 respectively) with respective membership function ranges, wherein the ranges of membership function of each of the SLS duration, the body joint vibration, and the CoM of body sway area are dynamically determined for the user, by the postural stability assessment system 100. By means of the comparison, the postural stability assessment system 100 identifies (314) membership function that matches each of the SLS duration, the body joint vibration, and the CoM of body sway area, for the user. Various actions in Fig. 3 can be performed in the same order or in a different order. Further, or one or more of the actions in method 300 can be omitted.

[0028] FIG. 4 is a flow diagram depicting steps involved in the process of dynamically determining range of membership functions of SLS duration, body joint vibrations, and body sway area of a user, using the postural stability assessment system, according to some embodiments of the present disclosure. The postural stability assessment system 100 collects (402) user specific parameters such as but not limited to age of the user, geographical location of the user and so on, as inputs for dynamically determining ranges of membership functions for the user. These values are then compared (404) with a learning model that specifies criteria for selecting the ranges. Once a matching criteria is found, the ranges of membership functions mapped against that particular criteria are selected as the ranges of membership functions for the user. Various actions in Fig. 4 can be performed in the same order or in a different order. Further, or one or more of the actions in method 400 can be omitted.

[0029] The written description describes the subject matter herein to enable any person skilled in the art to make and use the embodiments. The scope of the subject matter embodiments is defined by the claims and may include other modifications that occur to those skilled in the art. Such other modifications are intended to be within the scope of the claims if they have similar elements that do not differ from the literal language of

the claims or if they include equivalent elements with insubstantial differences from the literal language of the claims.

[0030] The embodiments of present disclosure herein addresses unresolved problem of postural stability assessment. The embodiment, thus provides mechanism for postural stability assessment based on SLS duration, body joint vibrations, and body sway area of a user, providing a system thereof.

[0031] It is to be understood that the scope of the protection is extended to such a program and in addition to a computer-readable means having a message therein; such computer-readable storage means contain program-code means for implementation of one or more steps of the method, when the program runs on a server or mobile device or any suitable programmable device. The hardware device can be any kind of device which can be programmed including e.g. any kind of computer like a server or a personal computer, or the like, or any combination thereof. The device may also include means which could be e.g. hardware means like e.g. an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of hardware and software means, e.g. an ASIC and an FPGA, or at least one microprocessor and at least one memory with software modules located therein. Thus, the means can include both hardware means and software means. The method embodiments described herein could be implemented in hardware and software. The device may also include software means. Alternatively, the embodiments may be implemented on different hardware devices, e.g. using a plurality of CPUs.

[0032] The embodiments herein can comprise hardware and software elements. The embodiments that are implemented in software include but are not limited to, firmware, resident software, microcode, etc. The functions performed by various modules described herein may be implemented in other modules or combinations of other modules. For the purposes of this description, a computer-usable or computer readable

medium can be any apparatus that can comprise, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device.

[0033] The illustrated steps are set out to explain the exemplary embodiments shown, and it should be anticipated that ongoing technological development will change the manner in which particular functions are performed. These examples are presented herein for purposes of illustration, and not limitation. Further, the boundaries of the functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternative boundaries can be defined so long as the specified functions and relationships thereof are appropriately performed. Alternatives (including equivalents, extensions, variations, deviations, etc., of those described herein) will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein. Such alternatives fall within the scope and spirit of the disclosed embodiments. Also, the words "comprising," "having," "containing," and "including," and other similar forms are intended to be equivalent in meaning and be open ended in that an item or items following any one of these words is not meant to be an exhaustive listing of such item or items, or meant to be limited to only the listed item or items. It must also be noted that as used herein and in the appended claims, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

[0034] Furthermore, one or more computer-readable storage media may be utilized in implementing embodiments consistent with the present disclosure. A computer-readable storage medium refers to any type of physical memory on which information or data readable by a processor may be stored. Thus, a computer-readable storage medium may store instructions for execution by one or more processors, including instructions for causing the processor(s) to perform steps or stages consistent with the embodiments described herein. The term "computer-

readable medium" should be understood to include tangible items and exclude carrier waves and transient signals, i.e., be non-transitory. Examples include random access memory (RAM), read-only memory (ROM), volatile memory, nonvolatile memory, hard drives, CD ROMs, DVDs, flash drives, disks, and any other known physical storage media.

[0035] It is intended that the disclosure and examples be considered as exemplary only, with a true scope and spirit of disclosed embodiments being indicated by the following claims.

CLAIMS

1. A processor-implemented method for postural stability assessment of a user, said method comprising:

collecting spatio-temporal information of joints of a user for one or more actions performed by the user, pertaining to a Single Limb Stance (SLS) duration, body joint vibration, and body sway area, of the user being monitored for postural stability assessment, via one or more hardware processors;

determining the SLS duration, the body joint vibration, and the body sway area, of said user as falling under at least one respective category, via the one or more hardware processors, by comparing values of the SLS duration, the body joint vibration, and the body sway area, with a range of corresponding membership functions, wherein the range of the corresponding membership functions is dynamically determined associated with each user, wherein the membership function refers to classifications each of the SLS time duration, the body joint vibration, and the body sway area under different categories defined by ranges of values;

dynamically generating a postural stability index score for said user, based on said determined at least one category of the SLS duration, the body joint vibration, and the body sway area, and at least one rule, via the one or more hardware processors; and

automatically assessing, by the hardware processor, postural stability of said user, based on said postural stability index score.

2. The method as claimed in claim 1, wherein dynamically determining the range of membership functions comprise of:

collecting values for parameters having impact on the user's health;

comparing the values of the parameters with a learning model to determine the category for selection of the range of the membership functions; and

determining the range of membership function of the SLS duration, the body joint vibration, and the body sway area, that matches the collected values of the parameters.

3. A system for postural stability assessment of a user, said system comprising:

a processor; and

a memory module comprising a plurality of instructions, said plurality of instructions configured to cause the processor to:

monitor an action being performed by a user and collecting spatio-temporal information of joints of a user pertaining to the action being performed by the user, by an Input/Output (I/O) module of the system;

determine a value corresponding to Single Limb Stance (SLS) duration of the user, based on the spatio-temporal information, by a SLS duration measurement module of the system;

determine a value corresponding to body joint vibration of the user, based on the spatio-temporal information, by a body joint vibration determination module of the system;

determine a value corresponding to body sway area of the user, based on the spatio-temporal information, by

a sway area determination module of the system;

dynamically determine the SLS duration, the body joint vibration, and the body sway area, of said user as falling under at least one respective category, by a stability index generation module of the system by comparing values of the SLS duration, the body joint vibration, and the body sway area, with a range of corresponding membership functions, wherein the range of the corresponding membership functions is dynamically determined associated with each user, wherein the membership function refers to classifications each of the SLS time duration, the body joint vibration, and the body sway area under different categories defined by ranges of values;

generate a postural stability index score for said user, based on said determined at least one category of the SLS duration, the body joint vibration, and the body sway area and at least one rule, by a stability index generation module of the system; and

automatically assess postural stability of said user, based on said postural stability index score, by a stability assessment module of the system.

4. The system as claimed in claim 3, wherein the stability index generation module is configured to dynamically determine the range of membership functions corresponding to the SLS duration, the body joint vibration, and the body sway area, by:

collecting values of the parameters having impact on user's health, using the I/O module;

comparing the spatio-temporal information with a learning model; and

determining a range membership functions of the SLS duration, the body joint vibration, and the body sway area, that matches the collected values of the parameters.

5. One or more non-transitory machine readable information storage mediums comprising one or more instructions which when executed by one or more hardware processors causes:

collecting spatio-temporal information of joints of a user for one or more actions performed by the user, pertaining to a Single Limb Stance (SLS) duration, body joint vibration, and body sway area, of the user being monitored for postural stability assessment, via one or more hardware processors;

determining the SLS duration, the body joint vibration, and the body sway area, of said user as falling under at least one respective category, via the one or more hardware processors by comparing values of the SLS duration, the body joint vibration, and the body sway area, with a range of corresponding membership functions, wherein the range of the corresponding membership functions is dynamically determined associated with each user, wherein the membership function refers to classifications each of the SLS time duration, the body joint vibration, and the body sway area under different categories defined by ranges of values;

dynamically generating a postural stability index score for said user, based on said determined at least one category of the SLS duration, the body joint vibration, and the body sway area and at least one rule, via the one or more hardware processors; and

automatically assessing postural stability of said user, based on said postural stability index score, via the one or more hardware processors.

6. The one or more non-transitory machine readable information storage mediums of claim 5, wherein the one or more instructions which when executed by the one or more hardware processors cause dynamic determination of the range of membership functions by:

collecting values of the parameters having impact on user's health;

comparing the values of the parameters with a learning model; and

determining a range of membership functions of the SLS duration, the body joint vibration, and the body sway area, that matches the collected values of the parameters.