

CONNECTED KIOSK FOR THE REAL-TIME ASSESSMENT OF FALLS RISK

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of U.S. Provisional Patent Application Serial No. 62/632,918 filed on February 20, 2018 and titled “Connected Kiosk for the Real-Time Assessment of Falls Risk,” and is related to U.S. Patent Application Serial No. 16/169,760 filed on October 24, 2018 and titled “Computing Devices with Improved Interactive Animated Conversational Interface Systems,” which are hereby incorporated by reference in their entirety.

FIELD OF THE TECHNOLOGY

[0002] Embodiments of the disclosure relate to a deployable fall risk assessment kiosk. In particular, the present disclosure relates to systems and methods providing real-time assessment of falls risk.

BACKGROUND

[0003] The approaches described in this section could be pursued, but are not necessarily approaches that have previously been conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

[0004] Fall risk assessment has become an integral part of the provision of health care to aged Americans. This coupled with the fact that the rapidly aging population of the United States has a great desire to maintain independence has led to the identification of a number of risk factors associated with falling. Unfortunately, most risk factor assessments take place in the office of a certified medical professional or in a brick-and-mortar research laboratory. This results in three primary limitations associated with the current fall risk assessment paradigm: 1) there is a travel component related to an individual’s ability to complete a

comprehensive fall risk assessment; 2) the traditional hardware and software costs associated with comprehensive fall risk assessment are prohibitive to the wide-spread conduction of these assessments; and 3) due to the logistical difficulties associated with conducting comprehensive falls risk assessments, individuals are commonly tested only once or twice per year.

[0005] These problems associated with comprehensive fall risk assessment have yet to be fully solved by currently available systems. While evidence suggests that the known factors associated with increased risk in falling can be identified and corrected, most currently available methods of comprehensive fall risk assessment are not patient-centric. Additionally, current assessment systems are not mobile and do not incorporate multiple methods of fall risk screening.

SUMMARY

[0006] According to some embodiments, the present technology is directed to a method for providing real-time assessment of falling risk, the method comprising: (a) providing a user with a survey comprising questions directed to eliciting information regarding assessing falls risk across a plurality of domains; (b) receiving the elicited information comprising answers to the questions that are indicative of a risk of falling of the user; (c) recording, via a depth camera system, depth video data of an activity of the user; (d) determining, based on the depth video data, at least one spatio-temporal gait characteristic associated with the activity performed by the user; (e) conducting a quantitative fall risk analysis based on the at least one spatio-temporal gait characteristic and the elicited information; and (f) displaying at least a portion of the quantitative fall risk analysis to the user.

[0007] In some embodiments, the present disclosure is directed to a system of one or more computers which can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination thereof installed on the system that in operation causes or cause the system to perform actions and/or method steps as described herein. For example, embodiments may include a system for providing real-time assessment of falling risk, the system comprising: (a) a kiosk; (b) a tablet device communicatively coupled to the kiosk; (c) a depth camera system communicatively coupled to the kiosk; (d) at least one processor; and (e) a memory storing processor-executable instructions, wherein the at least one processor is configured to implement the following operations upon executing the processor-executable instructions: (i) providing a user with a survey comprising questions directed to eliciting information regarding assessing falls risk across a plurality of domains; (ii) receiving the elicited information comprising answers to the questions that are indicative of a risk of falling of the user; (iii) recording, via a depth camera system, depth video data of an activity of the user; (iv) determining, based on the depth video data, at least one spatio-temporal gait characteristic associated with the activity performed by the user; (v) conducting a

quantitative fall risk analysis based on the at least one spatio-temporal gait characteristic and the elicited information; and (vi) displaying at least a portion of the quantitative fall risk analysis to the user.

[0008] In another embodiment, the present disclosure comprises a non-transitory computer readable medium having embodied thereon instructions being executable by at least one processor to perform a method for providing real-time assessment of falling risk, the method comprising: (a) providing a user with a survey comprising questions directed to eliciting information regarding assessing falls risk across a plurality of domains; (b) receiving the elicited information comprising answers to the questions that are indicative of a risk of falling of the user; (c) recording, via a depth camera system, depth video data of an activity of the user; (d) determining, based on the depth video data, at least one spatio-temporal gait characteristic associated with the activity performed by the user; (e) conducting a quantitative fall risk analysis based on the at least one spatio-temporal gait characteristic and the elicited information; and (f) displaying at least a portion of the quantitative fall risk analysis to the user.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, where like reference numerals refer to identical or functionally similar elements throughout the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate embodiments of concepts that include the claimed disclosure, and explain various principles and advantages of those embodiments.

[0010] FIG. 1 shows a high-level block diagram of an exemplary system configured to provide a comprehensive fall risk assessment, according to the subject disclosure.

[0011] FIG. 2 shows a high-level block diagram of an exemplary system for providing and processing a comprehensive survey, according to the subject disclosure.

[0012] FIGS. 3a-3c illustrate instances of an exemplary graphical user interface configured to facilitate receiving comprehensive survey responses, according to the subject disclosure.

[0013] FIG. 4 shows a high-level block diagram of an exemplary system for providing and processing gait analysis, according to the subject disclosure.

[0014] FIGS. 5a-5b illustrate exemplary graphical representations of a functional assessment of the gait analysis, according to the subject disclosure.

[0015] FIG. 6 illustrates an exemplary graphical user interface having functional movement analysis results, according to the subject disclosure.

[0016] FIG. 7 shows a high-level block diagram of an exemplary system configured to provide evidence-based recommendations based on comparative data, according to the subject disclosure.

[0017] FIG. 8 illustrates an exemplary graphical user interface having results of the comprehensive fall risk assessment.

[0018] FIG. 9 illustrates an exemplary graphical user interface configured to provide recommendations based on an environmental survey, according to the subject disclosure.

[0019] FIG. 10 illustrates an exemplary depiction of an electronic caregiver image (ECI) avatar configured to guide a user through the completion of the comprehensive fall risk assessment, according to the subject disclosure.

[0020] FIG. 11 illustrates an exemplary depiction of the ECI avatar providing representative examples of functional tests to be performed by a user, according to the subject disclosure.

[0021] FIG. 12 depicts a process flow diagram showing a method for providing a comprehensive fall risk assessment, according to the subject disclosure.

[0022] FIG. 13 illustrates an exemplary computer system that may be used to implement embodiments of the present disclosure.

DETAILED DESCRIPTION

[0023] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosure. It will be apparent, however, to one skilled in the art, that the disclosure may be practiced without these specific details. In other instances, structures and devices may be shown in block diagram form only in order to avoid obscuring the disclosure. It should be understood, that the disclosed embodiments are merely exemplary of the invention, which may be embodied in multiple forms. Those details disclosed herein are not to be interpreted in any form as limiting, but as the basis for the claims.

[0024] Various exemplary embodiments described and illustrated herein relate to a computing device configured to provide a patient-centric and mobile method of comprehensive fall risk assessment. The computing device may comprise a kiosk fall risk assessment system that performs a survey and gait analysis on individuals using a validated survey research instrument and a depth camera. Notably, the kiosk fall risk assessment system may utilize one or more interfaces, cameras, and sensors other than electrocardiograph (ECG). The completion of the survey and instructions for the gait analysis are provided to the user via a conversational interface system, as described in greater detail in related U.S. Patent Application Serial No. 16/169,760 filed on October 24, 2018 and titled "Computing Devices with Improved Interactive Animated Conversational Interface Systems," which is incorporated by reference in its entirety. The gait analysis incorporates the conversational interface system, a depth camera, a tablet device, and algorithms and machine learning to calculate one or more gait characteristics of the individual and fall risk scores. The results of the comprehensive survey, the gait characteristics, and the fall risk scores may then be provided to the individual through the conversational interface and kiosk.

[0025] FIG. 1 depicts a kiosk fall risk assessment system 100 configured to provide a comprehensive fall risk assessment of a user. In various embodiments, the

kiosk fall risk assessment system 100 includes a kiosk 120, a communications network 140, a comprehensive survey system 160, and a gait analysis system 170. The kiosk 120 may include or be coupled to a tablet device 120 and a depth camera system 150. A user 110 utilizes the kiosk system 120 through a tablet device 130 that is coupled to a communications network 140, such as the Internet or cellular network. An Electronic Caregiver system may be installed on the tablet device 130 configured to provide a comprehensive fall risk assessment for the user 110, as will be described in greater detail throughout the present disclosure. To be sure, the tablet device 130 and kiosk 120 may be replaced with, or take the form of, any suitable computing device, such as those described with respect to FIG. 13. The depth camera system 150 facilitates a functional movement assessment to measure one or more parameters of the user's movement. While not shown, it is to be understood that the kiosk fall risk assessment system 100 may further comprise any number or combination of sensors, including video camera systems, movement sensors, vibration sensors, or the like.

[0026] The comprehensive fall risk assessment is based on results from one or both of the comprehensive survey system 160 and the gait analysis system 170. The comprehensive survey system 160 and/or the gait analysis system may be cloud-based, or comprise one or more remote servers. It is to be understood that the one or more servers providing services for the comprehensive survey system 160 and the gait analysis system 170 may be the same remote servers, separate remote servers, or have one or more shared servers. Through an assessment of the comprehensive survey system 160 and/or the gait analysis system 170, the kiosk fall risk assessment system 100 facilitates providing the user 110 with clinically relevant data describing their overall risk of falling.

[0027] The communications network 140 may include a wireless or wire network, or a combination thereof. For example, the network may include one or more of the following: the Internet, local intranet, PAN (Personal Area Network), LAN (Local Area Network), WAN (Wide Area Network), MAN (Metropolitan Area Network),

virtual private network (VPN), storage area network (SAN), frame relay connection, Advanced Intelligent Network (AIN) connection, synchronous optical network (SONET) connection, digital T1, T3, E1 or E3 line, Digital Data Service (DDS) connection, DSL (Digital Subscriber Line) connection, Ethernet connection, ISDN (Integrated Services Digital Network) line, dial-up port such as a V.90, V.34 or V.34bis analog modem connection, cable modem, ATM (Asynchronous Transfer Mode) connection, or an FDDI (Fiber Distributed Data Interface) or CDDI (Copper Distributed Data Interface) connection. Furthermore, the communications may also include links to any of a variety of wireless networks including, WAP (Wireless Application Protocol), GPRS (General Packet Radio Service), GSM (Global System for Mobile Communication), CDMA (Code Division Multiple Access) or TDMA (Time Division Multiple Access), cellular phone networks, GPS, CDPD (cellular digital packet data), RIM (Research in Motion, Limited) duplex paging network, Bluetooth radio, or an IEEE 802.11-based radio frequency network. The network can further include or interface with any one or more of the following: RS-232 serial connection, IEEE-1394 (Firewire) connection, Fiber Channel connection, IrDA (infrared) port, SCSI (Small Computer Systems Interface) connection, USB (Universal Serial Bus) connection, or other wired or wireless, digital or analog interface or connection, mesh or Digi® networking.

[0028] The comprehensive survey system 160 may utilize an interactive, conversational, text-based interaction and a three-dimensional Electronic Caregiver Image (ECI) avatar that allow a user to complete various forms using voice conversation and cloud-based talk-to-text technology. The comprehensive survey system 160 will be described in greater detail with respect to FIGS. 2, 3a, 3b, and 3c.

[0029] The gait analysis system 170 is configured to assess and quantify one or more spatio-temporal gait characteristics, and a capability for completion, of the user 110 from one or more functional assessments. Functional assessments may include physical actions performed by the user, such as walking, sitting, turning, etc. The

gait analysis system 170 will be described in greater detail with respect to FIGS. 4, 5a, 5b, and 6.

[0030] FIG. 2 depicts a high-level block diagram of an exemplary system 200 for providing and processing a comprehensive survey using the comprehensive survey system 160. It is to be understood that the exemplary system 200 may be a portion of the kiosk fall assessment system 100 illustrated in FIG. 1. In various embodiments, the comprehensive survey system 160 is coupled with an electronic caregiver derived interactive animated conversational interface system having an interactive, conversational text-based communication system (referred to herein as a conversational interface) 180 and an Electronic Caregiver Image (ECI) avatar 190. Examples of the conversational interface 180 and the ECI avatar 190 are described in related U.S. Patent Application Serial No. 16/169,760 filed on October 24, 2018 and titled "Computing Devices with Improved Interactive Animated Conversational Interface Systems," which is incorporated by reference in its entirety.

[0031] Through the exemplary system 200, the ECI avatar 190 engages with the user 110 to provide a survey comprising a series of questions directed to eliciting information regarding assessing falls risk across a plurality of domains, and receiving the elicited information comprising answers to the questions that are indicative of a risk of falling of the user. The ECI avatar 190 may communicate in multiple languages. The exemplary system 200 provides the user 110 with an option of selecting methods for data input, methods comprising either type-based data entry or voice communication data entry.

[0032] Following the user input of data, including the elicited information, the data may be transmitted from the tablet device 130, to the kiosk 120, through the communications network 140 to the conversational interface 180 and/or comprehensive survey system 160. The conversational interface 180 analyzes the data input and determines redundancy against data input errors. In response to determining an error in the data input, the conversational interface 180 causes feedback to be provided to the user 110 for correction of errors, for example by the

ECI avatar 190. The conversational interface 180 may also transmit the input data to the comprehensive survey system 160, or inform the comprehensive survey system 160 of the results of the error determination.

[0033] To assess data for accuracy in real-time, the conversational interface 180 utilizes a catalogue of inputs to determine whether a data type input by the user 110 matches a defined catalogue data type. As such, through the use of cloud-based applications such as the conversational interface 180 and comprehensive survey system 160, the exemplary system 200 assesses the input data, determines whether errors exist in the input data, executes a continuation decision process, and provides a response to the user in real time. In general, the real time response may be provided to the user in a suitable period of time in which the user may wait, such as less than 1.0 second. Once data has been assessed for accuracy and all input data is entered, the comprehensive survey system 160 encrypts user input data and proceeds with transmitting the data to a cloud-based primary key design database for storage.

[0034] The exemplary system 200 also provides a web browser comprising the three-dimensional ECI avatar 190 for interactive communication with the user 110. This ECI avatar 190 provides the user with an interactive experience during which the user is guided through the completion of the comprehensive fall risk assessment. As the assessment is completed by the user, the ECI avatar 190 provides real-time feedback in conversational form in an effort to simplify and streamline the form completion by the user.

[0035] The ECI avatar 190 is displayed to the user 110 via a graphical user interface of the tablet device 130. The ECI avatar 190, via the tablet device 130, presents the series of questions to the user, the series of questions assessing falls risk across one or more domains. The domains, described in Table 1 below, are inclusive of the History, Medication, Environmental, Physical and Vision aspects of a user.

[0036] Table 1. Domains of fall risk assessed by the comprehensive survey system incorporated into the kiosk fall risk assessment system and sample inquiry areas for each of the domains.

Domain	Example Information Collected
History	1. Age 2. History of Falls 3. Assistive Device Use 4. Arthritis Diagnosis
Medication	1. Medication List 2. Experiencing of Side Effects 3. Number of Pharmacists 4. Pharmacy Consult Frequency
Environmental	1. Lighted Stairways from Top to Bottom 2. Floors Clear of Clutter 3. Non-Skid Rugs
Physical	1. Extended Timed Up-and-Go 2. Functional Reach Test
Vision	1. Wearing of Corrective Lenses as Prescribed 2. Vision Test within Last Year 3. Snellen Eye Score

[0037] The kiosk 120 provides the user 110 with access to talk-to-text functionality. The kiosk 120 provides the user 110 access to cloud-based services comprising computing capacity for the provision of both voice and text communication using the ECI avatar 190. As such, upon initiation of the comprehensive survey system 160 by the user 110, the ECI avatar 190 facilitates requesting the data necessary for completion of the comprehensive survey by way of simple conversation.

[0038] In certain embodiments, the exemplary system 200 validates survey data input by the user 110. Once survey response data from the user 110 are received by the kiosk 120 and transmitted to the conversational interface 180 via communications

network 140, the conversational interface 180 compares the data type (e.g. yes/no, words, numbers, etc.) of the input to predefined data types stored in a validation utility. Thus, the conversational interface 180 assesses the validity of data input types provided by the user 110. Upon determining the input is valid by the validation utility, the conversational interface 180 activates a progression decision program, which causes the kiosk 120 to move on to the next item contained in the comprehensive survey to be inquired of the user 110. Alternatively, upon determining the input is invalid by the validation utility, the progression decision program is not activated, and instead the conversational interface 180 triggers the comprehensive survey system 190 to inform the user 110 of the invalid data input. The kiosk 120, via the tablet device 130 and ECI avatar 190, informs the user 110 that the previous data input is invalid and asks the survey question again.

[0039] FIGS. 3a-3c illustrate instances of an exemplary graphical user interface 300 configured to facilitate receiving comprehensive survey responses. FIGS. 3a-3c depict the various decision paths based on input data from the user. It is to be understood that the graphical user interface 300 may be a part of the tablet device 130 depicted in FIGS. 1-2, or another suitable display coupled to the kiosk 120.

[0040] FIG. 3a depicts an initial set of uncompleted form fields displayed to the user 110 on the tablet device 130. FIG. 3b depicts the presentation of input data to the user 110 on the tablet device 130 that has been determined to be valid by the conversational interface 180. FIG. 3c depicts an invalid data input response from the ECI avatar 190.

[0041] FIG. 4 illustrates an exemplary system 400 for providing and processing a gait analysis using the gait analysis system 170. The gait analysis system 170 may include a body tracking module 172 and a movement parameter module 174, as will be described in greater detail below. It is to be understood that the exemplary system 400 may be a portion of the kiosk fall assessment system 100 illustrated in FIG. 1. In various embodiments, the kiosk 120 is further configured to facilitate assessing and quantifying one or more spatio-temporal gait characteristics of the

user 110, as well as the user's capability for completion of functional assessments.

Several examples of the spatio-temporal gait characteristics are described in Table 2.

[0042] Table 2. Functional movement parameters determined by the gait analysis system provided to user via the kiosk fall risk assessment system.

Quantified Variable	Definition
Gait Velocity	Linear distance traveled by the user per unit time.
Stride Length	Linear distance from points of successive foot strike of the same foot.
Step Length	Linear distance from point of foot strike for the contralateral foot.
Step Width	Linear distance in the frontal plane from point of foot strike for the contralateral foot.
Time in Stance	Percentage of the gait cycle during which the foot is in contact with the ground.
Time in Swing	Percentage of the gait cycle during which the foot is not in contact with the ground.
Time in Double Support	Percentage of the gait cycle during which both feet are in contact with the ground.
Stance time Variability	Average variability associated with the user stance time over the course of ten assessments.
Swing time Variability	Average variability associated with the user swing time over the course of ten assessments.
Timed Up-and-Go Test Duration	Duration (in seconds) it requires the user to complete functional assessment.
Timed Up-and-Go Test Turn Duration	Duration (in seconds) it requires the user to complete the turning portion of the functional assessment.
Timed Up-and-Go Test Stand Duration	Duration (in seconds) it requires the user to complete the sit-to-stand portion of the functional assessment.
Timed Up-and-Go Test Sit Duration	Duration (in seconds) it requires the user to complete the stand-to-sit portion of the functional assessment.
30-second Chair Stand Repetitions	Number of sit-to-stand repetitions the user completes during test period (30 seconds).
30-second Chair Stand Decay Rate	Rate of time decay associated with each repetition completed by the user during the testing period (30 seconds).

[0043] To perform the gait analysis of a functional assessment, the exemplary system 400 utilizes the depth camera system 150 and the gait analysis system 170.

The kiosk 120 initiates a functional assessment by inquiring of the readiness of the user 110. Following an acknowledgement of readiness by the user 110, the kiosk 120 initiates a video depth recording, via depth camera system 150, as the user walks and/or performs the recommended functional assessments. The user 110 performs the activity or activities necessary for the functional assessment as indicated by the kiosk 120 in the movement performance area 115. During performance of the functional test by the user 110, the kiosk 120 uses the depth camera system 150 to record a depth video of the activity.

[0044] The depth video is transmitted by the kiosk 120, either in real-time, at the completion of each activity, or the completion of the functional assessment, to the gait analysis system 170 via the communications network 140. The body tracking module 172 applies a body tracking algorithm to the depth video, including determining a position and an orientation of the user in space for the duration of the depth video data. The body tracking algorithm may include determining a location within the depth video of one or more limbs of the user 110, and tracking the position and orientation of the one or more limbs for each frame within the depth video data. The movement parameter module 174 may process the body tracking information produced by the body tracking module 172 to determine the one or more spatio-temporal gait characteristics of the user 110. For example, the movement parameter module 174 may determine the gait velocity of the user 110 by calculating the linear distance traveled by the user 110 divided by the length of time required for the user 110 to travel that distance. The one or more spatio-temporal gait characteristics may be stored in a database associated with the gait analysis system 170, the kiosk 120, the tablet device 130, or any combination thereof.

[0045] To be sure, while the gait analysis system 170, including the body tracking module 172 and movement parameter module 174, are shown as being remote from the kiosk 120 over communications network 140, embodiments of the present disclosure include having the gait analysis system 170 in the kiosk 120 or tablet device 130.

[0046] FIGS. 5a and 5b depict a graphical user interface 500 showing a representation of an activity of a functional assessment. The graphical user interface 500 may be presented to the user 110 via the tablet device 130 as shown in FIG. 4, for example. The representation may include a graphical depiction of the user 510, movement performance area 515, kiosk 520, tablet device 530, and depth camera system 550. The graphical user interface 500 may further depict a representative field of view 555 of the depth camera system 150 such that the user 110 may be informed as to the boundaries of the movement performance area 115. In particular, FIG. 5a illustrates an activity of a functional assessment involving the user 110 turning left from a stationary position. FIG. 5b illustrates another activity of a functional assessment including repeatedly walking back and forth in the movement performance area 115.

[0047] FIG. 6 illustrates an exemplary graphical user interface 600 having functional movement analysis results, which, in various embodiments, are presented to the user 110 via the tablet device 130. The results may include a label of the spatio-temporal gait characteristic, the determined value of the spatio-temporal gait characteristic, and a brief description of the spatio-temporal gait characteristic. The kiosk fall risk assessment system may provide the determined spatio-temporal gait characteristics to the user in real-time.

[0048] FIG. 7 depicts a cloud-based normative data storage 700 coupled to a portion of the kiosk fall risk assessment system 100 as shown in FIG. 1. The cloud-based normative data storage 700, which may comprise one or more remote servers, provides evidence-based consultative recommendations the user 110 based on the results of the comprehensive fall risk assessment. The one or more remote servers may have computing capabilities as described in the exemplary computing system depicted in FIG. 13. To provide the recommendations following completion of the fall risk assessment, the kiosk may access one or more cloud-based normative data storage 700 instances having at least one of: 1) normative data for functional movement tests; 2) known risk ratios for functional movement data; 3) falls history

risk ratios; 4) data describing known risks and interactions associated with medication; 5) evidenced-based recommendations for low-risk environmental designs; 6) normative data associate with vision; or 7) known risk ratios associated with vision variables. The normative data and risk ratios may be determined from a plurality of survey responses and functional assessments of other users received by the cloud-based normative data storage 700 from the comprehensive survey system 160 and gait analysis system 170. The kiosk 120 may receive the normative data, risk ratios, and recommendations from the cloud-based normative data storage 700 via communications network 140, and compare the data determined from the comprehensive survey system 160 and gait analysis system 170 for the particular user 110 to the data received from the cloud-based normative data storage 700. Based on the comparison, the kiosk 120 may provide various recommendations to the user 110 based on the comprehensive fall risk assessment. The recommendations facilitate decreasing the fall risk associated with the user 110.

[0049] For example, the kiosk 120 may determine a score for the user regarding a particular domain of the comprehensive survey. In one or more embodiments, the kiosk fall risk assessment system 100 utilizes one or more artificial intelligence systems and/or machine learning algorithms to determine the score. The kiosk 120 may further receive a predetermined threshold from the cloud-based normative data storage 700 regarding the particular domain. Upon determining that the score exceeds the predetermined threshold, the kiosk 120 may determine that one or more recommendations received from the cloud-based normative data storage 700 associated with the particular domain are applicable to the user 110 and display the one or more recommendations to the user 110.

[0050] FIGS. 8 and 9 depict providing the user with one or more recommendations based on the comprehensive fall risk assessment. FIG. 8 illustrates a graphical user interface 800 having recommendations 820 determined based on one or more survey responses and determined spatio-temporal gait characteristics presented to the user in a comprehensive fall risk assessment 810. For example, the

ECI avatar 830 provides a recommendation 820 that the user should consider decluttering his or her home environment to reduce the risk of falling, based on the environment score present in the user's comprehensive fall risk assessment 810. The ECI avatar 830 likewise recommends that the user discuss with a healthcare provider ways in which he or she could increase gait velocity, for example based on the determined spatio-temporal gait characteristic shown in FIG. 6 which is below a normative value threshold. FIG. 9 shows a graphical user interface 900 having an environment survey 910, recommendations 920, and ECI avatar 930. Based on the results of the environmental survey 910, in particular the user input that the user has area rugs but no rug-liners underneath, dual-sided tape, or non-skid backs, as well as that the user has floors, stairs, and landings not clear of clutter, the ECI avatar 930 provides the recommendation 920 that the user should replace his or her rugs with non-skid rugs to help reduce the risk of falling.

[0051] FIG. 10 depicts an exemplary ECI avatar 1000 configured to guide the user through the completion of the comprehensive fall risk assessment. The ECI avatar 1000 facilitates guiding the user 110 through the data collection process in a manner that serves three purposes: 1) to reduce user errors in data collection processes performed by the kiosk 120; 2) to provide an interactive method of click-free and type-free communication that is easily completed by the user 110 and 3) to provide both instructions and representative examples of the various tests to be performed by the user 110. For example, as depicted in FIG. 11, the ECI avatar 1100 may provide a representative example of a functional test to be performed by the user. In particular the ECI avatar 1100 depicted in FIG. 11 is demonstrating how the user should properly transition from a sitting position to a standing position such that the kiosk fall risk assessment system is able to adequately record depth information and properly analyze the activity. As such, the kiosk fall risk assessment system may utilize cloud-based resources coupled to the kiosk to allow survey responses to be received and assessed in a manner that is less intimidating than a more traditional laboratory setting or medical professional's office.

[0052] FIG. 12 is a process flow diagram showing a method 1200 for providing a comprehensive fall risk assessment according to one or more example embodiments. The method 700 may be performed by processing logic that may comprise hardware (e.g., dedicated logic, programmable logic, and microcode), software (such as software run on a general-purpose computer system or a dedicated machine), or a combination thereof. In one or more example embodiments, the processing logic resides at the kiosk 120, the tablet device 130, the comprehensive survey system 160, or the gait analysis system 170, or combinations thereof.

[0053] As shown in FIG. 12, the method 1200 may commence at operation 1210, with providing a user with a survey comprising questions directed to eliciting information regarding assessing falls risk across a plurality of domains. The user may be provided with the survey via kiosk, and more specifically, an ECI avatar represented by a graphical user interface of a coupled tablet device.

[0054] At operation 1220, the method 1200 may proceed with receiving the elicited information comprising answers to the questions that are indicative of a risk of falling of the user.

[0055] At operation 1230, the method 1200 may include recording, via a depth camera system, depth video data of an activity of the user.

[0056] At operation 1240, the method 1200 may proceed with determining, based on the recorded depth video data, at least one spatio-temporal gait characteristic associated with the activity performed by the user. The determining may include tracking body movements via a body tracking module and calculating the spatio-temporal gait characteristic via a movement parameter module, as previously described. It is to be understood that the calculation of the spatio-temporal gait characteristic may be performed by the kiosk or by a remote server such as the gait analysis system 170 depicted in FIG. 1. In this way, the kiosk may determine the at least one spatio-temporal gait characteristic by transmitting the depth video data to such a remote server for processing, and receiving the spatio-temporal gait characteristics from the remote server.

[0057] At operation 1250, the method 1200 may include conducting a quantitative fall risk analysis based on the at least one spatio-temporal gait characteristic and the elicited information comprising the answers to the survey questions. The quantitative gait analysis may include determining an overall fall risk score based on a set of spatio-temporal gait characteristics.

[0058] At operation 1260, the method 1200 may proceed with displaying at least a portion of the quantitative fall risk analysis to the user.

[0059] Optionally, at operation 1270, the method 1200 may include providing, based on the quantitative fall risk analysis, a recommendation to the user.

[0060] FIG. 13 shows a diagrammatic representation of a computing device for a machine in the example electronic form of a computer system 1300, within which a set of instructions for causing the machine to perform any one or more of the methodologies discussed herein can be executed. In example embodiments, the machine operates as a standalone device, or can be connected (e.g., networked) to other machines. In a networked deployment, the machine can operate in the capacity of a server, a client machine in a server-client network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine can be a personal computer (PC), tablet PC, game console, set-top box (STB), personal digital assistant (PDA), television device, cellular telephone, portable music player (e.g., a portable hard drive audio device), web appliance, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that separately or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein. Computer system 1300 can be an instance of the kiosk 120, tablet device 130, comprehensive survey system 160, gait analysis system 170, or cloud-based normative data storage 700.

[0061] The example computer system 1300 includes a processor or multiple processors 1305 (e.g., a central processing unit (CPU), a graphics processing unit

(GPU), or both), and a main memory 1310 and a static memory 1315, which communicate with each other via a bus 1320. The computer system 1300 can further include a video display unit 1325 (e.g., a liquid-crystal display (LCD), organic light emitting diode (OLED) display, or a cathode ray tube (CRT)). The computer system 1300 also includes at least one input device 1330, such as an alphanumeric input device (e.g., a keyboard), a cursor control device (e.g., a mouse), a microphone, a digital camera, a video camera, and so forth. The computer system 1300 also includes a disk drive unit 1335, a signal generation device 1340 (e.g., a speaker), and a network interface device 1345.

[0062] The drive unit 1335 (also referred to as the disk drive unit 1335) includes a machine-readable medium 1350 (also referred to as a computer-readable medium 1350), which stores one or more sets of instructions and data structures (e.g., instructions 1355) embodying or utilized by any one or more of the methodologies or functions described herein. The instructions 1355 can also reside, completely or at least partially, within the main memory 1310, static memory 1315 and/or within the processor(s) 1305 during execution thereof by the computer system 1300. The main memory 1310, static memory 1315, and the processor(s) 1305 also constitute machine-readable media.

[0063] The instructions 1355 can further be transmitted or received over a communications network 1360 via the network interface device 1345 utilizing any one of a number of well-known transfer protocols (e.g., Hyper Text Transfer Protocol (HTTP), CAN, Serial, and Modbus). The communications network 1360 includes the Internet, local intranet, Personal Area Network (PAN), Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN), virtual private network (VPN), storage area network (SAN), frame relay connection, Advanced Intelligent Network (AIN) connection, synchronous optical network (SONET) connection, digital T1, T3, E1 or E3 line, Digital Data Service (DDS) connection, Digital Subscriber Line (DSL) connection, Ethernet connection, Integrated Services Digital Network (ISDN) line, cable modem, Asynchronous Transfer Mode (ATM)

connection, or an Fiber Distributed Data Interface (FDDI) or Copper Distributed Data Interface (CDDI) connection. Furthermore, communications network 1360 can also include links to any of a variety of wireless networks including Wireless Application Protocol (WAP), General Packet Radio Service (GPRS), Global System for Mobile Communication (GSM), Code Division Multiple Access (CDMA) or Time Division Multiple Access (TDMA), cellular phone networks, Global Positioning System (GPS), cellular digital packet data (CDPD), Research in Motion, Limited (RIM) duplex paging network, Bluetooth radio, or an IEEE 802.11-based radio frequency network.

[0064] While the machine-readable medium 1350 is shown in an example embodiment to be a single medium, the term “computer-readable medium” should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term “computer-readable medium” shall also be taken to include any medium that is capable of storing, encoding, or carrying a set of instructions for execution by the machine and that causes the machine to perform any one or more of the methodologies of the present application, or that is capable of storing, encoding, or carrying data structures utilized by or associated with such a set of instructions. The term “computer-readable medium” shall accordingly be taken to include, but not be limited to, solid-state memories, optical and magnetic media. Such media can also include, without limitation, hard disks, floppy disks, flash memory cards, digital video disks, random access memory (RAM), read only memory (ROM), and the like.

[0065] The example embodiments described herein can be implemented in an operating environment comprising computer-executable instructions (e.g., software) installed on a computer, in hardware, or in a combination of software and hardware. The computer-executable instructions can be written in a computer programming language or can be embodied in firmware logic. If written in a programming language conforming to a recognized standard, such instructions can be executed on

a variety of hardware platforms and for interfaces to a variety of operating systems. Although not limited thereto, computer software programs for implementing the present method can be written in any number of suitable programming languages such as, for example, Hypertext Markup Language (HTML), Dynamic HTML, XML, Extensible Stylesheet Language (XSL), Document Style Semantics and Specification Language (DSSSL), Cascading Style Sheets (CSS), Synchronized Multimedia Integration Language (SMIL), Wireless Markup Language (WML), Java™, Jini™, C, C++, C#, .NET, Adobe Flash, Perl, UNIX Shell, Visual Basic or Visual Basic Script, Virtual Reality Markup Language (VRML), ColdFusion™ or other compilers, assemblers, interpreters, or other computer languages or platforms.

[0066] Thus, the technology for comprehensive fall risk assessment is disclosed. Although embodiments have been described with reference to specific example embodiments, it will be evident that various modifications and changes can be made to these example embodiments without departing from the broader spirit and scope of the present application. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.