

SYSTEMS AND METHODS FOR IDENTIFYING BODY JOINT LOCATIONS BASED ON SENSOR DATA ANALYSIS

DESCRIPTION

Priority Claim

[001] This patent application claims priority to India Application No. 201621027388, filed on August 10, 2016. The entire contents of the aforementioned application are incorporated herein by reference.

Technical Field

[002] This disclosure relates generally to sensor data analysis, and more particularly to systems and methods for identifying body joint locations based on sensor data analysis.

Background

[003] Joint motion analysis is an important aspect of health monitoring / rehabilitation of patients suffering from neurological disorders, post stroke patients, and elderly subjects. Joint movement data capture is traditionally done using clinical devices such as Vicon, which is marker-based and extremely expensive and ill-suited for prolonged rehabilitation therapy. Kinect® is a marker-less motion capture device that is being used for its low cost, portability and ease of cost when compared to its expensive counterpart. The accuracy of Kinect® as an alternative to Marker-based systems has been widely studied and there are extensive reports on its validity and reliability in comparison to Vicon. However, the reports indicate a lower accuracy of the human body joint information provided by Kinect® skeletal data. The skeleton data provided by Kinect® requires further optimization to improve its accuracy and allow effective and reliable assessment.

SUMMARY

[004] 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.

[004a] According to a first aspect of the present disclosure, there is provided a processor implemented method including: obtaining, by one or more hardware processors, one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints; estimating, using said one or more input data, by said one or more hardware processors, in a first set of frames, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths; iteratively identifying, by said one or more hardware processors, one or more probable correct body joint locations in a bounded

neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint; performing, by said one or more hardware processors, a comparison of (i) a body segment length associated with each of said one or more probable correct body joint locations and (ii) a reference length; identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison; determining a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate; and identifying, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

[004b] According to a second aspect of the present disclosure, there is provided a system including: a memory storing instructions; one or more communication interfaces; and one or more hardware processors coupled to said memory using said one or more communication interfaces, wherein said one or more hardware processors are configured by said instructions to: obtain one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprising three dimensional (3D) coordinates pertaining to one or more skeleton joints, estimate, using said one or more input data, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths, iteratively identify one or more probable correct body joint locations in a bounded neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint, perform a comparison of (i) a body segment length associated with each of said one or more probable correct body joint locations and (ii) a reference length; identify at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison, determine a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate, and identify, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in

direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

[004c] According to a third aspect of the present disclosure, there is provided one or more non-transitory machine readable information storage mediums including one or more instructions which when executed by one or more hardware processors causes: obtaining, by one or more hardware processors, one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints; estimating, using said one or more input data, by said one or more hardware processors, in a first set of frames, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths; iteratively identifying, by said one or more hardware processors, one or more probable correct body joint locations in a bounded neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint; performing, by said one or more hardware processors, a comparison of (i) a body segment length associated with each of said one or more probable correct body joint locations and (ii) a reference length; identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison; determining a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate; and identifying, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

[004d] For example, in an embodiment, a hardware processor implemented method for identifying body joint locations is provided. The method comprises obtaining, by one or more hardware processors, input data comprising skeletal data, depth data, and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein the one or more input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints. The method further comprises estimating, using the one or more input data, by the one or more hardware processors, one or more body joint locations and a body segment length of one or

more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths. In an embodiment, the one or more body segment lengths are based on a Euclidean distance between adjacent skeleton joints. One or more probable correct body joint locations are identified in a bounded neighborhood around the one or more body joint locations that are previously obtained in a previous frame, wherein the one or more probable correct body joint locations are iteratively identified based on the depth data and the RGB data. In an example embodiment, a search region is defined for identifying the one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint in a single frame. The method further comprises performing, by the one or more hardware processors, a comparison of (i) a body segment length associated with each of the one or more probable correct body joint locations and (ii) a reference length. In an embodiment, the reference length is derived based on the estimate of the one or more body segment lengths. A subset of the one or more probable correct body joint locations are identified as one or more candidate body joint locations based on the comparison. In an embodiment, the subset of the one or more probable correct body joint locations are identified as one or more candidate body joint locations based on the comparison resulting in a minimal body segment length variation. A physical orientation of each body segment pertaining to each of the one or more candidate body joint locations is determined by segmenting one or more 3D coordinates of each body segment based on the depth data and performing an analysis on each segmented 3D coordinate. A (corrected) body joint location is identified from the one or more candidate body joint locations based on a minimal deviation in direction from the physical orientation of a corresponding body segment along with a feature descriptor of the RGB data and the depth data, wherein the minimal deviation is based on the depth data, and, wherein the minimal deviation is based on one or more actions performed by the user.

[005] In another embodiment, a system for identifying a body joint location is provided. The system comprises a memory storing instructions, one or more communication interfaces, and one or more hardware processors coupled to the memory using the one or more communication interfaces, wherein the one or more hardware processors are configured by the instructions to: obtain one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein the one or more input data comprising three dimensional (3D) coordinates pertaining to one or more skeleton joints. The skeletal data, depth data and red, green, and blue (RGB) data are captured by a sensor (e.g., Kinect® sensor). The one or more hardware processors are further configured by the instructions to estimate, using the one or more input data, one or more body joint locations and a body segment length of one or more body segments connecting to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths. In an embodiment, one or more body segment lengths are based on a Euclidean distance between adjacent skeleton joints. In an embodiment, the system is further configured to identify one or more probable correct body joint locations in a bounded

neighborhood around the one or more body joint locations that are previously obtained from a previous frame, wherein the one or more probable correct body joint locations are iteratively identified based on the depth data and the RGB data. In an embodiment, a search region is defined to identify the one or more probable correct body joint locations based on a radius equivalent to a displacement of a corresponding skeleton joint in a single frame.

[006] The system further performs a comparison of (i) a body segment length associated with each of the one or more probable correct body joint locations and (ii) a reference length. In an embodiment, the reference length is derived based on the estimate of the one or more body segment lengths. The system further identifies a subset of the one or more probable correct body joint locations as one or more candidate body joint locations based on the comparison. In an embodiment, the subset of the one or more probable correct body joint locations are identified as one or more candidate body joint locations based on the comparison resulting in a minimal body segment length variation. In other words, probable correct body joint locations having a minimal body segment length variation with respect to the reference length are identified as one or more candidate body joint locations.

[007] The system is further configured to determine a physical orientation of each body segment pertaining to each of the one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on the depth data and performing an analysis on each segmented 3D coordinate. The system is further configured to identify, from the one or more candidate body joint locations, a (corrected) body joint location based on a minimal deviation in direction from the physical orientation of a corresponding body segment along with a feature descriptor of the RGB data and the depth data, wherein the minimal deviation is based on the depth data, and wherein the minimal deviation is based on one or more actions performed by the user. In an embodiment, a body joint location having a minimal deviation in direction from the physical orientation of a corresponding body segment is identified as a corrected joint body location along with a feature descriptor of the RGB data and the depth data.

[008] In yet another embodiment, one or more non-transitory machine readable information storage mediums comprising one or more instructions is provided. The one or more instructions which when executed by one or more hardware processors causes obtaining input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein the input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints. The one or more instructions which when executed by one or more hardware processors further causes estimating, using the one or more input data, one or more body joint locations and a body segment length of one or more body segments connecting to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths. In an embodiment, the one or more body segment lengths are based on a Euclidean distance between

CLAIMS

1. A processor implemented method comprising:

obtaining, by one or more hardware processors, one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints;

estimating, using said one or more input data, by said one or more hardware processors, in a first set of frames, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths;

iteratively identifying, by said one or more hardware processors, one or more probable correct body joint locations in a bounded neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint;

performing, by said one or more hardware processors, a comparison of (i) a body segment length associated with each of said one or more probable correct body joint locations and (ii) a reference length;

identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison;

determining a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate; and

identifying, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

2. The processor implemented method of claim 1, wherein identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations is based on said comparison resulting in a minimal body segment length variation.
3. The processor implemented method of claim 1, wherein said estimate of said one or more body segment lengths is based on a Euclidean distance between adjacent skeleton joints.
4. The processor implemented method of claim 1, wherein said reference length is derived based on said estimate of said one or more body segment lengths.
5. A system comprising:
 - a memory storing instructions;
 - one or more communication interfaces; and
 - one or more hardware processors coupled to said memory using said one or more communication interfaces, wherein said one or more hardware processors are configured by said instructions to:
 - obtain one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprising three dimensional (3D) coordinates pertaining to one or more skeleton joints,
 - estimate, using said one or more input data, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one or more body joint locations and (ii) an estimate of one or more body segment lengths,
 - iteratively identify one or more probable correct body joint locations in a bounded neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint,
 - perform a comparison of (i) a body segment length associated with each of said

one or more probable correct body joint locations and (ii) a reference length;

identify at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison,

determine a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate, and

identify, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

6. The system of claim 5, wherein at least a subset of said one or more probable correct body joint locations are identified as one or more candidate body joint locations based on said comparison resulting in a minimal body segment length variation.

7. The system of claim 5, wherein said estimate of said one or more body segment lengths is based on a Euclidean distance between adjacent skeleton joints.

8. The system of claim 5, wherein said reference length is derived based on said estimate of said one or more estimated body segment lengths.

9. 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:

obtaining, by one or more hardware processors, one or more input data comprising skeletal data, depth data and red, green, and blue (RGB) data pertaining to at least one user at one or more time stamps, wherein said one or more input data comprises three dimensional (3D) coordinates pertaining to one or more skeleton joints;

estimating, using said one or more input data, by said one or more hardware processors, in a first set of frames, one or more body joint locations and a body segment length of one or more body segments connected to corresponding skeleton joints to obtain (i) an estimate of one

or more body joint locations and (ii) an estimate of one or more body segment lengths;

iteratively identifying, by said one or more hardware processors, one or more probable correct body joint locations in a bounded neighborhood around said one or more body joint locations that are previously obtained, wherein said one or more probable correct body joint locations are iteratively identified based on said depth data and said RGB data, wherein a search region is defined for identifying said one or more probable correct body joint locations using a radius equivalent to a displacement of a corresponding skeleton joint;

performing, by said one or more hardware processors, a comparison of (i) a body segment length associated with each of said one or more probable correct body joint locations and (ii) a reference length;

identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations based on said comparison;

determining a physical orientation of each body segment pertaining to each of said one or more candidate body joint locations by segmenting one or more 3D coordinates of each body segment based on said depth data and performing an analysis on each segmented 3D coordinate; and

identifying, from said one or more candidate body joint locations, a body joint location based on a minimal deviation in direction from said physical orientation of a corresponding body segment along with a feature descriptor of said RGB data and said depth data, wherein said minimal deviation is based on said depth data, and wherein said minimal deviation is based on one or more actions performed by said user.

10. The one or more non-transitory machine readable information storage mediums of claim 9, wherein identifying, by said one or more hardware processors, at least a subset of said one or more probable correct body joint locations as one or more candidate body joint locations is based on said comparison resulting in a minimal body segment length variation.

12. The one or more non-transitory machine readable information storage mediums of claim 9, wherein said estimate of said one or more body segment lengths is based on a Euclidean distance between adjacent skeleton joints.

13. The one or more non-transitory machine readable information storage mediums of claim 9, wherein said reference length is derived based on said estimate of said one or more body segment lengths.