

DESCRIPTION

METHOD AND SYSTEM FOR TRAJECTORY ANALYSIS BY COMBINING SFM WITH PDR BASED ON BIM MODEL

TECHNICAL FIELD

The present disclosure relates to the field of intelligent positioning technologies, and in particular to a method and a system for matching and analyzing panoramic photos shot by mobile terminals and PDR motion trajectories with a building information modeling (BIM) model by combining structure from motion (SFM) with pedestrian dead reckoning (PDR) technologies.

BACKGROUND

In the fields of architecture and engineering, the building information modeling (BIM) model has become a commonly used tool for designing, constructing, and maintaining buildings. Panoramic photos can provide more visual vision information to record and show actual situations of buildings. However, it is still a challenge to match and analyze panoramic photos with the BIM model to achieve more accurate trajectory analysis.

In the prior art, only one input medium, panoramic video, is used to achieve spatial relationship matching with the BIM model. However, due to poor effects of a purely visual solution in scenes with poor lighting or great lighting changes, false matching and matching failures may be present.

SUMMARY

In order to solve the above problems, the present disclosure introduces a PDR sensor and uses PDR as a reference for the trajectory. This can make up for the defects of the visual solution in a poor environment, where the PDR dominates in correcting the trajectory to assist an image SFM method, so as to obtain more accurate

positioning information. The present disclosure specifically provides the following technical solutions:

A method for trajectory analysis by combining SFM with PDR based on a BIM model includes the following steps:

S1: turning on Bluetooth and WiFi function buttons in a mobile terminal, opening a corresponding application (app) for data processing, establishing connection to a panoramic camera through the WiFi, and establishing connection to an inertial measurement unit (imu) sensor module through the Bluetooth; manually selecting a used camera model in the app, adapting imaging of different cameras in the app to ensure that a generated raw panoramic photo faces front of a photographer;

S2: calling an insta360 panoramic camera to shoot and acquire a panoramic video; processing the panoramic video into a panoramic photo, and generating an SFM trajectory by using an SFM method;

S3: acquiring a raw motion data file through the imu sensor, the raw motion data file including a timestamp, a quaternion, a linear acceleration, and an angular acceleration; generating a complete PDR motion trajectory by calculation on data acquired by the imu sensor by using a PDR algorithm;

S4: fusing and correcting the SFM trajectory and the PDR motion trajectory, and matching the fused trajectory with the BIM model; and

S5: uploading each piece of data to a cloud database for storage, and generating a corresponding data information set corresponding to each collection task, the data information set including panoramic photo information, position information, attitude information, and information of a serial number of the BIM model.

Optionally, in the S2, the process of processing the panoramic video includes:

S21: extracting a frame from the panoramic video into the panoramic photo;

S22: unrolling the panoramic photo into a planar photo according to a set field of view (FOV) and a set orientation; and

S23: generating a motion trajectory by calculation on the unrolled planar photo by using the SFM method; and obtaining a camera pose and a camera position for each

frame of image by performing feature extraction, matching, and camera motion estimation on the planar photo.

Optionally, in the S3, specific steps for generating the PDR motion trajectory include:

S31: obtaining the data of the linear acceleration, the angular acceleration, the timestamp, and the quaternion from the imu sensor, defining an attitude with a position at an origin as an initial attitude, and setting an initial velocity to 0;

S32: filtering and denoising the raw sensor data;

S33: detecting a start and an end of a pace based on a local maximum of the linear acceleration, and identifying a data segment during the pace as walking motion data based on a set threshold;

S34: for the pace identified in each segment, setting a starting velocity to 0, integrating the linear acceleration in three dimensions to obtain a velocity increment; adding the velocity increment to a current velocity to obtain an updated velocity; integrating the velocity in the three dimensions to obtain a position increment; adding the position increment to a current position to obtain an updated position; and

S35: repeating the steps S33 to S34, until all motion data is processed, such that the complete PDR motion trajectory is generated.

Optionally, in the step S4, the matching includes:

synchronizing a time of the PDR motion trajectory with a time of a positioning point selected on the app, such that the two times are synchronized to count from 1 by using different time offsets, and matching starting points and second points corresponding to time axes in the two pieces of data; and after calculating rotation, translation, and scaling relationships of the two corresponding sets of points on a plane, correcting the data of the PDR motion trajectory to the BIM model.

Optionally, the matching further includes:

after the data of the PDR motion trajectory is fused with the BIM model, each point of a result obtained by the PDR having a corresponding position on the BIM model,

and each point having a corresponding timestamp;
selecting a position of the PDR as a base, and revising position and angle information therein by using SFM trajectory data obtained by the SFM;
processing, after obtaining the position base of the PDR, each generated segment of SFM trajectory data to obtain a revised SFM trajectory, the processing including:
copying a raw PDR position as trajectory data to be revised in real time;
time-sorting each segment of SFM trajectory data, and using a starting point and an ending point of the data sorted in time as a starting point and an ending point of the corresponding SFM trajectory, which are then matched with the data of the PDR motion trajectory, implementing transformation of rotation, translation, and scaling using the two sets of points by matching position information of the timestamps of the starting point and the ending point of the SFM trajectory with the corresponding timestamps of the PDR; updating, after completing the transformation of rotation, translation, and scaling, orientation information of the photo at each position by using a photo angle calculated by the SFM, and applying the orientation information to the revised SFM trajectory; and
retrieving the revised complete trajectory again after matching each segment of SFM trajectory to the PDR trajectory and revising the position and angle of the data; and using the raw PDR data as the base still for the data whose position and angle orientation has not been revised by the SFM trajectory, and assigning a piece of angle information calculated by the SFM for replacement.

Optionally, the correction further includes:

placing, for photos that are not corrected using the SFM trajectory, each of the photos in a corresponding position, and then searching for an orientation of each of the photos; obtaining an orientation vector of each position based on a difference between front and back positions of the motion trajectory, and determining the orientation of the photo based on an included angle between the orientation vector and a horizontal axis of the BIM model, the orientation being used for correcting the photo angle.

Optionally, the S5 further includes:

when viewing and analyzing the information set, loading the information set, and generating a sky dome with rotation angles at a corresponding spatial position of the BIM model, the sky dome being a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.

Optionally, the panoramic camera has a direction locking function, allowing to keep an output video in a direction of a fixed angle with a lens of the camera when synthesizing the video.

The present disclosure further provides a system for trajectory analysis by combining SFM with PDR based on a BIM model. The system includes:

a terminal app, configured to establish connection to a panoramic camera and an imu sensor module, and manually select a camera model;

a data processing module, configured to receive and process data uploaded by the terminal app at a cloud server, and generate a corresponding processing task; and

a data fusion module, configured to upload matched position and attitude of each panoramic photo with the BIM model to a cloud database as an information set.

Optionally, the system further includes:

an information viewing module, configured to view and analyze the information set; load the information set, and generate a sky dome with rotation angles at a corresponding spatial position of the BIM model, the sky dome being a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.

The present disclosure has the following beneficial technical effects. The present disclosure provides a method and a system for trajectory analysis by combining SFM with PDR based on a BIM model. The present disclosure can realize trajectory analysis of buildings or indoor space, and provide more accurate positioning and navigation services. In the method of the present disclosure, firstly, a panoramic camera and an IMU sensor module are connected through a mobile terminal, and a

camera model is selected for adaptation. Then, a panoramic video is shot by using the panoramic camera and processed into a panoramic photo. Next, an SFM trajectory is generated by using an SFM method, and the camera pose and motion trajectory for each frame of image are obtained by performing feature extraction, matching, and camera motion estimation on a planar photo. Meanwhile, a raw motion data file is acquired through the IMU sensor, including a timestamp, a quaternion, a linear acceleration, and an angular acceleration. A complete PDR motion trajectory is generated by calculation using a PDR algorithm, including pace detection, attitude correction, and position update. Next, the SFM trajectory and the PDR motion trajectory are fused and corrected, and matched with the BIM model. By removing a time offset, rotation, translation, and scaling relationships are calculated, and the data of the PDR motion trajectory is corrected to the BIM model. Finally, the matched position and attitude of each panoramic photo with the BIM model are uploaded to a cloud database as a piece of data, and a corresponding information set is generated. By loading the information set and generating a sky dome with rotation angles at a corresponding spatial position of the BIM model, the information set can be viewed and analyzed conveniently. Compared to the prior art, by combining SFM with PDR technologies, the present disclosure can accurately locate the trajectory and attitude of the collected panoramic photo in a building or indoor space, and analyze the construction process. Meanwhile, through matching with the BIM model, the present disclosure can provide more visual and accurate trajectory visualization results and comparison with the BIM model.

BRIEF DESCRIPTION OF THE DRAWINGS

To describe the technical solutions in the embodiments of the present disclosure more clearly, the following briefly describes the accompanying drawings required for the embodiments. Apparently, the accompanying drawings in the following description show merely some embodiments of the present disclosure, and those of ordinary skill in the art may still derive other drawings from these accompanying

drawings without creative efforts.

FIG. 1 is a flowchart of a method for trajectory analysis by combining SFM with PDR based on a BIM model according to an embodiment of the present disclosure.

FIG. 2 is a framework diagram of a system for trajectory analysis by combining SFM with PDR based on a BIM model according to an embodiment of the present disclosure.

FIG. 3 is a diagram of a motion trajectory generated by a PDR algorithm according to the present disclosure.

FIG. 4 is a diagram of a PDR motion trajectory after scaling processing according to the present disclosure.

DETAILED DESCRIPTION

The embodiments of the present disclosure are described in detail below with reference to the accompanying drawings.

The embodiments of the present disclosure are illustrated below through noted implementations, and other advantages and effects of the present disclosure can be easily understood by those skilled in the art based on the contents disclosed herein.

It is apparent that the described embodiments are only a part of the embodiments of the present disclosure, but not all of them. The present disclosure can also be implemented or applied through other different specific embodiments. Various modifications or changes to the details in the description can be made based on different perspectives and applications without departing from the spirit of the present disclosure. It should be noted that, unless conflicting, the embodiments and features of the embodiments below may be combined with each other. Based on the embodiments in the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative work shall fall within the protection scope of the present disclosure.

It should be noted that various aspects of the embodiments are described below that are within the scope of the appended claims. It should be apparent that the aspects

described herein may be embodied in a wide variety of forms and that any noted structure and/or function described herein is merely illustrative. Based on the present disclosure, those skilled in the art should understand that one aspect described herein may be implemented independently from any other aspect, and that two or more of these aspects may be combined in various ways. For example, a device may be implemented and/or a method may be practiced by using any number and aspects set forth herein.

It should be further noted that the illustrations provided in the following embodiments only illustrate basic concepts of the present disclosure in a schematic manner.

Furthermore, in the following description, specific details are provided to facilitate a thorough understanding of the examples. However, those skilled in the art will understand that practice may be performed without these noted details.

An object of the present disclosure is to provide a method for trajectory analysis by combining SFM with PDR based on a BIM model, aiming to solve the problem of low accuracy of motion trajectory positioning analysis under a BIM model.

In order to make the above objects, features, and advantages of the present disclosure more clearly and easily understandable, a further detailed description of the present disclosure will be provided in conjunction with the accompanying drawings and specific embodiments.

Referring to FIG. 1, a method for trajectory analysis by combining SFM with PDR based on a BIM model according to an embodiment of the present disclosure is shown. The method includes the following steps:

In S1, Bluetooth and WiFi function buttons in a mobile terminal are turned on, a corresponding app for data processing is opened, a panoramic camera is connected through the WiFi, and an imu sensor module is connected through the Bluetooth; a used camera model is manually selected in the app, imaging of different cameras is adapted in the app to ensure that a generated raw panoramic photo faces front of a photographer.

In S2, an insta360 panoramic camera is called to shoot and acquire a panoramic video; the panoramic video is processed into a panoramic photo, and an SFM trajectory is generated by using an SFM method.

Optionally, in the S2, extracting the frame from the panoramic video into the panoramic photo is performed by processing each frame of the panoramic video, so as to convert it into the panoramic photo. Videos shot with a fisheye lens have a wide-angle field of view and can capture a wider scene, but due to the special shape of the lens, the image will appear curved. Therefore, each frame needs to be de-distorted to convert the curved image into a planar panoramic photo. The specific processing steps are as follows: First, each frame of the panoramic video needs to be de-distorted. This can be achieved by calculating and correcting using a fisheye lens distortion model to remove the curvature effect from the image. Next, each frame of de-distorted image is spliced together to form the panoramic photo. The splicing can be achieved by aligning the pixels of each frame and fusing them. In this way, each frame of the panoramic video can be converted into the panoramic photo. The panoramic photo is then unrolled to be converted into a planar photo. The unrolling processing can be achieved by mapping the pixels of the panoramic photo onto a plane according to certain rules. The unrolled planar photo can be more conveniently processed and analyzed later. Finally, the motion trajectory is generated from the unrolled planar photo by using the SFM method. SFM is a method for reconstructing scenes by analyzing feature points in images and camera motion. By performing feature extraction, matching, and camera motion estimation on the planar photo, the camera pose and motion trajectory for each frame of image can be obtained. This allows for better observation and analysis of scenes and motion in the panoramic video. The above processing process of the panoramic video can be implemented through the SDK of the camera.

Exemplarily, the SFM trajectory plotting analysis can be implemented based on but not limited to colmap software.

Optionally, the SFM method further includes:

feature extraction: extracting feature points from each frame of image in an image sequence, where common feature point algorithms include SIFT, SURF, ORB, etc.; feature matching: matching feature points between adjacent frames, and determining the matching relationship by calculating the similarity or distance between the feature points; motion estimation: estimating the camera motion between adjacent frames by using matched feature point pairs, where common methods include the RANSAC algorithm based on an essential matrix or a basis matrix; three-dimensional reconstruction: estimating a three-dimensional point cloud in the scene through triangulation or optimization methods based on the camera motion and depth information of the feature points; and trajectory optimization: optimizing the camera trajectory through optimization algorithms (such as bundle adjustment) to improve the accuracy of reconstruction results. Finally, the SFM method can generate the motion trajectory of the camera and the three-dimensional point cloud of the scene, i.e., the SFM trajectory.

In S3, a raw motion data file is acquired through the imu sensor, where the raw motion data file includes a timestamp, a quaternion, a linear acceleration, and an angular acceleration; a complete PDR motion trajectory is generated by calculation on data acquired by the imu sensor by using a PDR algorithm.

Optionally, the implementation process of generating the motion trajectory by using the PDR algorithm in step S3 is as follows:

Initialization includes defining an initial position and attitude: the position being the origin, and the attitude being an initial attitude; an initial velocity is set to 0. Data preprocessing includes filtering and denoising the raw motion data to reduce the impact of noise on the calculation. Gait detection includes detecting a start and an end of a pace based on a local maximum of the linear acceleration; and identifying a data segment during the pace as walking motion data based on a set threshold. Attitude correction includes correcting the attitude of the sensor by using the quaternion to eliminate the impact of attitude changes on the calculation. Velocity integration includes integrating the linear acceleration in three dimensions to obtain

a velocity increment; adding the velocity increment to a current velocity to obtain an updated velocity. Position integration includes integrating the velocity in the three dimensions to obtain a position increment; adding the position increment to a current position to obtain an updated position. Updating the timestamp includes updating the timestamp based on a sampling frequency and a pace detection result. The above steps are repeated until all the motion data is processed. FIG. 3 shows a diagram of a motion trajectory generated by a PDR algorithm.

Optionally, in the PDR algorithm:

Gait detection is to detect the local maximum of the linear acceleration to determine the start and the end of the pace. Attitude correction is to correct the attitude by using the quaternion, so as to adjust the attitude of the sensor to a reference attitude.

The calculation of velocity integration includes:

$\text{velocity increment} = \text{linear acceleration} * \text{time interval}$

$\text{updated velocity} = \text{current velocity} + \text{velocity increment}$

The calculation of position integration includes:

$\text{position increment} = \text{velocity} * \text{time interval}$

$\text{updated position} = \text{current position} + \text{position increment}$

The data such as the linear acceleration, the time interval, and the quaternion are acquired from the IMU sensor.

Optionally, in the present disclosure, the following filtering and denoising methods may be used for the data of the linear acceleration, the time interval, and the quaternion acquired from the IMU sensor:

Linear acceleration filtering: common linear acceleration filtering methods include low-pass filtering and Kalman filtering. Low-pass filtering can smooth the linear acceleration data by filtering out high-frequency noise, while Kalman filtering can filter the linear acceleration through state estimation and observation update.

Time interval filtering: time interval data is usually generated by a sensor sampling frequency, so outliers can be removed by simple threshold filtering. For example, a reasonable time interval range can be set, and time interval data beyond the range

can be regarded as outliers and filtered out.

Quaternion filtering: quaternion data usually requires attitude estimation and filtering. Common filtering methods include Kalman filtering, extended Kalman filtering, and unscented Kalman filtering. These filtering methods can filter and smooth the quaternion through state estimation and observation update.

Optionally, for the PDR algorithm, the direction of the image is estimated using geomagnetic and gyroscope data, and expressed by Euler angles E (i.e., yaw, pitch, and roll). The direction information of the image is expressed by the quaternion (a, b, c, d). The attitude of the imu sensor is corrected by using the quaternion (a, b, c, d), where a calculation formula for the direction error σ is as follows:

$$\sigma = a \cos\left(\frac{E' \cdot E_g}{|E'| + |E_g|}\right) \times \frac{180}{\pi}$$

In the formula, E' is an estimated image direction, and E_g is a true value of the image direction.

Optionally, during the shooting process, there is no need to select a plurality of points in the trajectory recording as in colmap. Compared to colmap where in order to prevent the corresponding points from being unable to be found due to the failure of reconstruction of some points, a plurality of positioning points are required to avoid certain problems, the PDR data will not be generated due to the imu data based on the time axis, and there will be no generation failure. The overall trajectory is complete on the time axis, so only two points are required to determine the starting point, orientation, and scale of the trajectory.

In S4, the SFM trajectory and the PDR motion trajectory are fused and corrected, and matched with the BIM model.

Optionally, after steps S2 and S3, two types of trajectory data can be obtained, one of which is data generated from panoramic photo frames by using a visual method, and the other is a trajectory obtained by integrating sensor data by using the imu sensor.

The relationship and usage of these two types of trajectories in matching with the BIM model are as follows:

First, the SFM trajectory is generated based on the plane on which the FOV of the picture is unrolled, so it has both the trajectory and the orientation of the photo after generating the result. However, due to the visual solution, in some places with poor lighting or similar scenes, the generated trajectory model may be divided into a number of segments or errors may occur.

Second, since the PDR trajectory does not involve images but only sensors, the trajectory is pure position information and does not carry the orientation of the photo. Therefore, the position is relatively correct, but the orientation of the photo needs to be determined by other methods.

Third, both of them have a common disadvantage, i.e., scale uncertainty. Since the scale of colmap is generated from photos shot by a monocular camera, the scale may have errors compared to the reality. The linear acceleration data used in PDR is normalized, i.e., divided by the value of the gravitational acceleration g . This is done to eliminate the impact of changes in the gravitational acceleration under different environments on trajectory analysis. However, since the gravitational acceleration calibrated in the sensor chip may be different from the gravitational acceleration in the current environment, the generated trajectory has an overall scaling factor. In other words, the trajectory shape generated by PDR is accurate, but may have an overall scaling deviation. This is due to the normalization of the linear acceleration data, because the normalized data will be affected by the gravitational acceleration. Therefore, when using PDR for trajectory analysis, it is necessary to take the scaling factor into account and make corresponding corrections or adjustments to ensure the accuracy and consistency of the trajectory. FIG. 4 shows a diagram of a PDR motion trajectory after scaling processing.

For these two types of data, in addition to the method in the prior art that only matches the panoramic video with the BIM model, the present disclosure further designs two new methods, one of which is to match only PDR data with the BIM

model, and the other is to use both PDR data and colmap data, which are fused and corrected, and matched with the BIM model.

In the first method, only the PDR data is fused with the BIM model.

The main difference between this method and the method of fusing colmap with the BIM model is that colmap requires a plurality of positioning points. Since colmap itself has generation failures, the SFM trajectory is split and placed in two adjacent positioning points, which can be considered as a method for reducing the risk of error by using a plurality of sets of positioning points because of the inability to find the positioning points due to generation failures. As a result, the entire trajectory is actually segmented, not completely continuous.

The PDR data is obtained by integrating continuous sensor data, and there will be no intermediate breaks caused by reconstruction, so there is no need for a plurality of positioning points for disaster recovery. Therefore, only one set of positioning points is needed to determine the starting point, direction, and scaling of the overall trajectory. Finally, the entire trajectory is complete, and has the same shape as when it was generated, and is not split.

Therefore, the final implementation logic of this method is as follows: A starting point is set when data is collected, and during the collection process, a correct second point that can be found on the model is selected. The setting times of these two points and their position coordinates in the BIM model are recorded.

In the matching process, the time offsets of the PDR and the positioning point are first removed, such that the times of both of them count from 1, and the starting points and the second points corresponding in time in the two pieces of data are matched. Since the matching is only performed in a plane relationship, after calculating relative rotation, translation, and scaling relationships for the two sets of points on the plane, the PDR data is corrected to the BIM model.

After the position is obtained, each photo needs to be placed in the corresponding position first, and then the orientation of each photo is searched for.

The Insta360 camera has a processing function of direction locking. When this

function is turned on when synthesizing a video, the output video is kept in a direction of a fixed angle with the lens of the camera (but due to the SDK, it can only be approximately ensured that the video is in a relatively fixed direction relative to the camera, and there may be offsets, which can be corrected in motion). In this mode, in most motions, the orientation of the photo can be basically determined according to front and back positions of the motion trajectory. An orientation vector of each position is obtained based on a difference between the front and back positions. The orientation of the photo is determined based on an included angle between the vector and a horizontal axis of the BIM model, where the orientation is used for correcting the photo angle.

It is assumed by default that the vector obtained from front and back points of each position represents the orientation of the photo, and that the synthesized panoramic photo has a perfect direction locking effect in the use of the SDK, with no offset. Therefore, in fact, due to the instability of the direction locking function, it is impossible to perfectly ensure that the direction and the orientation of the camera are completely consistent. In addition, during the motion, the vector of each position may be different from the actual motion. For example, variable motion will cause an angular gap between the vector and the orientation of the actual motion.

Due to the pure trajectory prediction, with no feature points between images for further correction, if there is an error in the angle produced in the final generation, there is no possibility of correction.

In the second method, data of SFM and PDR is fused for fusion with the BIM model. As with the first method, the PDR data is first fused with the BIM model, such that each point in the result obtained by the PDR has a corresponding position and a corresponding time on the BIM model.

After this, the position of the PDR is used as a base, and position and angle information therein is revised by using the data obtained by the SFM.

In this method, it is not required to fully match all data, as with the method using only the SFM. Since there is a piece of base position data, the data reconstructed by

colmap is allowed to be fragmented and multi-segmented. Therefore, sequential matching can be used to improve the processing efficiency in the feature point matching stage of the photo.

After obtaining the position base of the PDR in the previous step, each generated segment of SFM data is processed. Each segment of data will be sorted according to the output data of the SFM, and a starting point and an ending point of the data sorted in time will be used as corresponding starting point and ending point, which are then matched with the PDR trajectory data. The transformation of rotation, translation, and scaling is implemented by using these two sets of points, and the photo angle calculated by the SFM is used to assist this rotation transformation to obtain more accurate photo angle information.

After matching each segment of SFM trajectory to the PDR trajectory, the complete PDR trajectory will be retrieved again. For photos without the SFM and positions with angle correction, a piece of angle information will be assigned by using the first method for replacement.

In S5, matched position and attitude of each panoramic photo with the BIM model are uploaded to a cloud database as a piece of data, and a corresponding information set is generated.

Optionally, when the information set is viewed and analyzed, the information set is loaded, and a sky dome with rotation angles is generated at a corresponding spatial position of the BIM model. The sky dome is a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.

Referring to FIG. 2, a system for trajectory analysis by combining SFM with PDR based on a BIM model according to an embodiment of the present disclosure is shown. The system includes:

a terminal app, configured to establish connection to a panoramic camera and an imu sensor module, and manually select a camera model;

a data processing module, configured to receive and process data uploaded by the

terminal app at a cloud server, and generate a corresponding processing task; and a data fusion module, configured to upload matched position and attitude of each panoramic photo with the BIM model to a cloud database as an information set.

Optionally, the system further includes:

an information viewing module, configured to view and analyze the information set; load the information set, and generate a sky dome with rotation angles at a corresponding spatial position of the BIM model, the sky dome being a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.

The above are exemplary embodiments disclosed in the present disclosure, but it should be noted that various changes and modifications may be made without departing from the disclosed scope of the embodiments of the present disclosure as defined by the claims. The functions, steps, and/or actions of the method claims according to the disclosed embodiments described herein do not need to be performed in any noted order. Furthermore, although elements disclosed in the embodiments of the present disclosure may be described or claimed in an individual form, they may also be understood in plural unless explicitly limited to singular.

In the specification, the same and similar parts of the embodiments can be referred to each other, and each embodiment focuses on the differences from other embodiments. In particular, for the embodiments described later, the description is relatively simple, and reference may be made to some descriptions of the foregoing embodiments for relevant parts.

The above descriptions are only specific embodiments of the present disclosure, but the protection scope of the present disclosure is not limited to these. Any variations or substitutions that can be easily conceived by those skilled in the art within the technical scope disclosed herein should be covered within the protection scope of the present disclosure. Therefore, the protection scope of the present disclosure shall be subject to the protection scope of the claims.

CLAIMS

1. A method for trajectory analysis by combining structure from motion (SFM) with pedestrian dead reckoning (PDR) based on a building information modeling (BIM) model, comprising the following steps:

S1: turning on Bluetooth and WiFi function buttons in a mobile terminal, opening a corresponding application (app) for data processing, establishing connection to a panoramic camera through the WiFi, and establishing connection to an inertial measurement unit (imu) sensor module through the Bluetooth; manually selecting a used camera model in the app, adapting imaging of different cameras in the app to ensure that a generated raw panoramic photo faces front of a photographer;

S2: calling an insta360 panoramic camera to shoot and acquire a panoramic video; processing the panoramic video into a panoramic photo, and generating an SFM trajectory by using an SFM method;

S3: acquiring a raw motion data file through the imu sensor, the raw motion data file comprising a timestamp, a quaternion, a linear acceleration, and an angular acceleration; generating a complete PDR motion trajectory by calculation on data acquired by the imu sensor by using a PDR algorithm;

S4: fusing and correcting the SFM trajectory and the PDR motion trajectory, and matching the fused trajectory with the BIM model; and

S5: uploading each piece of data to a cloud database for storage, and generating a corresponding data information set corresponding to each collection task, the data information set comprising panoramic photo information, position information, attitude information, and information of a serial number of the BIM model,

wherein in the step S4, the matching comprises:

synchronizing a time of the PDR motion trajectory with a time of a positioning point selected on the app, such that the two times are synchronized to count from 1 by using different time offsets, and matching starting points and second points corresponding to time axes in the two pieces of data; and after calculating rotation,

translation, and scaling relationships of the two corresponding sets of points on a plane, correcting the data of the PDR motion trajectory to the BIM model, and the matching further comprises:

after the data of the PDR motion trajectory is fused with the BIM model, each point of a result obtained by the PDR having a corresponding position on the BIM model, and each point having a corresponding timestamp;

selecting a position of the PDR as a base, and revising position and angle information therein by using SFM trajectory data obtained by the SFM;

processing, after obtaining the position base of the PDR, each generated segment of SFM trajectory data to obtain a revised SFM trajectory.

2. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 1, wherein in the S2, the process of processing the panoramic video comprises:

S21: extracting a frame from the panoramic video into the panoramic photo;

S22: unrolling the panoramic photo into a planar photo according to a set field of view (FOV) and a set orientation; and

S23: generating a motion trajectory by calculation on the unrolled planar photo by using the SFM method; and obtaining a camera pose and a camera position for each frame of image by performing feature extraction, matching, and camera motion estimation on the planar photo.

3. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 1, wherein in the S3, specific steps for generating the PDR motion trajectory comprise:

S31: obtaining the data of the linear acceleration, the angular acceleration, the timestamp, and the quaternion from the imu sensor, defining an attitude with a position at an origin as an initial attitude, and setting an initial velocity to 0;

S32: filtering and denoising the raw sensor data;

S33: detecting a start and an end of a pace based on a local maximum of the linear acceleration, and identifying a data segment during the pace as walking motion data based on a set threshold;

S34: for the pace identified in each segment, setting a starting velocity to 0, integrating the linear acceleration in three dimensions to obtain a velocity increment; adding the velocity increment to a current velocity to obtain an updated velocity; integrating the velocity in the three dimensions to obtain a position increment; adding the position increment to a current position to obtain an updated position; and

S35: repeating the steps S33 to S34, until all motion data is processed, such that the complete PDR motion trajectory is generated.

4. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 1,

wherein the processing comprising:

copying a raw PDR position as trajectory data to be revised in real time;

time-sorting each segment of SFM trajectory data, and using a starting point and an ending point of the data sorted in time as a starting point and an ending point of the corresponding SFM trajectory, which are then matched with the data of the PDR motion trajectory, implementing transformation of rotation, translation, and scaling using the two sets of points by matching position information of the timestamps of the starting point and the ending point of the SFM trajectory with the corresponding timestamps of the PDR; updating, after completing the transformation of rotation, translation, and scaling, orientation information of the photo at each position by using a photo angle calculated by the SFM, and applying the orientation information to the revised SFM trajectory; and

retrieving the revised complete trajectory again after matching each segment of SFM trajectory to the PDR trajectory and revising the position and angle of the data; and using the raw PDR data as the base still for the data whose position and angle

orientation has not been revised by the SFM trajectory, and assigning a piece of angle information calculated by the SFM for replacement.

5. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claims 1 or 4, wherein the correction further comprises: placing, for photos that are not corrected using the SFM trajectory, each of the photos in a corresponding position, and then searching for an orientation of each of the photos; obtaining an orientation vector of each position based on a difference between front and back positions of the motion trajectory, and determining the orientation of the photo based on an included angle between the orientation vector and a horizontal axis of the BIM model, the orientation being used for correcting the photo angle.

6. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 1, wherein the S5 further comprises: when viewing and analyzing the information set, loading the information set, and generating a sky dome with rotation angles at a corresponding spatial position of the BIM model, the sky dome being a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.

7. The method for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 1, wherein the panoramic camera has a direction locking function, allowing to keep an output video in a direction of a fixed angle with a lens of the camera when synthesizing the video.

8. A system for trajectory analysis by combining SFM with PDR based on a BIM model, configured to implement the method for trajectory analysis by combining

SFM with PDR based on a BIM model according to any one of claims 1 to 7, the system comprising:

a terminal app, configured to establish connection to a panoramic camera and an imu sensor module, and manually select a camera model;

a data processing module, configured to receive and process data uploaded by the terminal app at a cloud server, and generate a corresponding processing task; and

a data fusion module, configured to upload matched position and attitude of each panoramic photo with the BIM model to a cloud database as an information set.

9. The system for trajectory analysis by combining SFM with PDR based on a BIM model according to claim 8, further comprising:

an information viewing module, configured to view and analyze the information set; load the information set, and generate a sky dome with rotation angles at a corresponding spatial position of the BIM model, the sky dome being a container for loading the panoramic photo, allowing standard planar picture viewing angles to be maintained from various viewing angles of the sky dome.