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(54) Title: METHOD, APPARATUS AND MEDIUM FOR PERFORMING 3D MODEL CREATION OF PEOPLE AND IDENTIFICATION OF PEOPLE VIA MODEL MATCHING

(57) Abstract: Provided are a model matching method that generates a model for an object using a sensor and compares structure data and surface data of the model with another model to match the two models, a storage medium on which the model matching method is recorded, and a device performing model matching.
Description

Title of Invention: METHOD, APPARATUS AND MEDIUM FOR PERFORMING 3D MODEL CREATION OF PEOPLE AND IDENTIFICATION OF PEOPLE VIA MODEL MATCHING

Technical Field

The present invention relates to a method, apparatus and storage medium for creating 3D models of biometric (living) entities from different types of camera data and performing a matching function between 3D models or parts models within another model. As matches of these parts of these 3D models are found, users can be uniquely identified. The camera data may be streams of 2D images from 2 or more cameras, or 2D images from single camera and depth images from depth camera(s), and may use infrared data, RGB data, depth data or other data, which is compared within our algorithm and used to create unique 3D models for living entities. This invention includes a method, apparatus and storage medium for performing matching between biometric models of a biometric object obtained through a sensor by comparing and analyzing the models. We compare/use 2D data to create 3D models of living organisms, each of which are unique to the person and can be used for multiple functions such as motion tracking and unique identification of an individual.

Background Art

The importance of motion tracking and authentication technology for verifying a user's identity is ever increasing. Particularly, the importance of biometric authentication has grown with uses of user's using biometric information such as identification through fingerprints, irises, facial recognition, DNA analysis, movement and voice related data. This is because the biometric information used in biometric authentication is unique to each person and can be represented by data values to uniquely identify each user.

The above-described biometric authentication schemes each have advantages and disadvantages in terms of required sensor, processing speed, and accuracy. Most of these methods transform 3D information such as fingerprints, irises and facial recognition and create 2D representations for unique identification. This invention is based on the creation of a 3D model from 2D data sources to create a more accurate, real-life like, model that is an accurate and unique representation of that person, and then using different methods to identify or authenticate these individuals as pattern matches with these models are found. One method does biometric authentication by finding and tracking veins in users and recreating a 3D representation of that part of the body. Other methods of biometric authentication use vein distributions as well,
since they are unique to each individual. Our method is very different because it preserves the 3D nature of veins in humans.

**Disclosure of Invention**

**Technical Problem**

[4] The present invention has been made in view of the above problem, namely, we provide a new method for biometric security. Accordingly, one aspect of the present invention is to provide an improved way to model biometric data and a new method for matching that can speed up the model matching process to reduce the time required and accuracy for user identification authentication. Also, our method is more difficult to fake because it is more detailed and in 3D versus 2D approaches such as with fingerprints or 2D palm vein patterns.

[5] Another aspect of the present invention is to ensure the reliability of the authentication result by improving the accuracy of the result while increasing the model matching speed by implementation of structure and surface analysis, 3D cell dynamic theory (6-DOF), and probability model matching theory described below.

[6] Aspects, features or objects of the present invention are not limited to those described above. Other aspects and salient features of the present invention will become apparent to those skilled in the art from the following detailed description.

**Solution to Problem**

[7] In accordance with an aspect of the present invention, there is provided a method for a system to perform 3D model creation and model matching.

[8] The method may include:

[9] - generating a first model for an object utilizing one or more sensors;

[10] - calculating the 6 degree of freedom (6-DOF) value of a first point located on the first model;

[11] - comparing the 6-DOF value of the first point with the 6-DOF value of a second point that is located in a second model being compared with the first model and matches the first point; and

[12] - applying the comparison result to a third point adjacent to the first point in the first model, and determining the probability range of a fourth point that is located in the second model and matches the third point.

[13] In one embodiment, the probability range may be a numerical representation of a cell in which the fourth point may exist in space.

[14] In one embodiment, the 6-DOF value may be a value or a range value indicating at least one point has moved in 3D space, orientation, and rotation.

[15] In one embodiment, the probability range may be determined by reflecting the elastic modulus between the first point and the third point in the comparison result.
In one embodiment, applying the comparison result may include calculating at least one of the direction of the position displacement change, the amount of displacement in rotation, and the amount of change in rotation between the first point and the third point.

In one embodiment, applying the comparison result may further comprises applying the direction or the rotation of the position displacement between the first point and the third point, to a transformation matrix defined for the first model and the second model, and obtaining a direction or a rotation of a position displacement between the second point and the fourth point, from the transformation matrix.

In one embodiment, the amount of displacement and the amount of change may be a value based on an absolute coordinate system, a value based on a relative coordinate system generated based on the axis of a reference point, or a value based on a relative coordinate system resulting from transformation between two matching points.

In one embodiment, applying the comparison result may include geometrically representing the probability for the position, rotation or direction based on a given space figure.

In one embodiment, model matching between the first model and the second model may be applied to at least one of a process of comparing structure data of the object and a process of comparing surface data of the object.

In one embodiment, the method may further comprise determining whether the first model and the second model are matched. It may be determined that the first model and the second model are matched with each other, if the comparison result of the structure data and the comparison result of the surface data are above or equal to a threshold value.

In one embodiment, upon determining that the first model and the second model are matched with each other, the comparison result of the structure data and the comparison result of the surface data may be transferred to scaled-up data.

In one embodiment, the method may further comprise extracting feature data from the structure data and the surface data. The feature data may be generated by utilizing at least one of the intensity, color, surface normal, curvature, vein, skin line, and relationship between features for a particular point.

In one embodiment, the structure data may be data about the vein distribution of the object and the surface data may be data about the skin of the object. The structure data and the surface data may be two-dimensional data or three-dimensional data.

In one embodiment, if the data constituting the first model is changed before determining whether the first model is matched with the second model, the changed data of the first model may be compared with the data of the second model.

In one embodiment, the method further comprises tracking a change of the 6-DOF
value of the first point and a change of the 6-DOF value of the second point for a duration of time, and generating a motion signature for the first model and the second model respectively by using the change of the 6-DOF values.

[27] In accordance with another aspect of the present invention, there is provided a system capable of performing 3D model creation and matching. The system may include a sensor unit configured to obtain data about an object the system may accept data from sensor units external to the system. The system may contain a software or hardware controller configured to match two models based on the data obtained from the sensor unit. The controller may generate a first model for an object utilizing one or more sensors of the sensor unit, calculate the 6 degree of freedom (6-DOF) value of a first point located on the first model, compare the 6-DOF value of the first point with the 6-DOF value of a second point that is located in a second model being compared with the first model and matches the first point, and apply the comparison result to a third point adjacent to the first point in the first model to determine the probability range of a fourth point that is located in the second model and matches the third point.

[28] In accordance with another aspect of the present invention, there may be a computer-readable storage medium, either internal or external to the system, for storing data, methods and 3D model to be used for 3D model creation and matching purposes.

[29] The model matching method may include:

[30] - generating a first model for an object utilizing one or more sensors;

[31] - calculating a 6 degree of freedom (6-DOF) value of a first point located on the first model;

[32] - comparing the 6-DOF value of the first point with the 6-DOF value of a second point that is located in a second model being compared with the first model and matches the first point;

[33] - applying the comparison result to a third point adjacent to the first point in the first model to determine the probability range of a fourth point that is located in the second model and matches the third point;

[34] - finding patches of mesh from on data source or model within another patch or 3D model; and

[35] - matching biometric signatures or identifiers within other models or data storage systems.

**Advantageous Effects of Invention**

[36] In a feature of the present invention, the following effects can be expected.

[37] First, the speed of the model matching process is improved. Hence, a large number of matching results can be examined rapidly, and the time required for authentication can be greatly reduced.
Second, the accuracy of the results of model matching performed in various environments is improved. Hence, accurate authentication results can be obtained rapidly.

Effects or advantages of the present invention are not limited to those described above. Other effects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description in conjunction with the annexed drawings.

**Brief Description of Drawings**

The accompanying drawings are included to provide an understanding of the present invention and constitute embodiments of the present invention together with the detailed description. However, the technical features of the present invention are not limited to a specific drawing, and the features disclosed in the drawings may be combined with each other to constitute a new embodiment. Reference numerals in each drawing refer to structural elements.

FIG. 1 illustrates a model matching process according to an embodiment of the present invention.

FIG. 2 illustrates various methods of model sensing by using at least one sensors.

FIG. 3 illustrates a structure analysis process in accordance with an embodiment of the present invention.

FIG. 4 illustrates a 2-DOF (degree of freedom) extension process in accordance with an embodiment of the present invention.

FIG. 5 illustrates a 6-DOF extension process in accordance with an embodiment of the present invention.

FIG. 6 illustrates a surface analysis process in accordance with an embodiment of the present invention.

FIG. 7 illustrates dynamic equilibrium in the surface analysis process in accordance with an embodiment of the present invention.

FIG. 8 is a flowchart of a model matching method in accordance with an embodiment of the present invention.

FIG. 9 is a flowchart of a model matching method in accordance with an embodiment of the present invention.

FIG. 10 shows flowcharts of a model matching in accordance with embodiments of the present invention.

FIG. 11 shows flowcharts of a motion model matching in accordance with embodiments of the present invention.

FIG. 12 illustrates an example of motion modeling in accordance with an embodiment of the present invention.

FIG. 13 is a block diagram of a device performing model matching in accordance
with an embodiment of the present invention.

**Mode for the Invention**

[54] The terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be understood that terms should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art. In some cases, particular terms may be defined to describe the invention in the best manner. Accordingly, the meaning of specific terms or words used in the specification and the claims should be construed in accordance with the spirit of the invention.

[55] The following embodiments are the result of combining the constituent elements and features of the present invention in a specific form. Each component or feature may be considered optional unless otherwise expressly stated. Each component or feature may constitute an embodiment without being combined with another component or feature. Some of the elements and/or features may be combined to constitute an embodiment of the present invention. The order of the operations described in the embodiments may be varied. Some configurations or features of certain embodiments may be included in other embodiments, or may be replaced with corresponding configurations or features of other embodiments.

[56] Descriptions of well-known steps, functions or structures incorporated herein may be omitted to avoid obscuring the subject matter of the present invention.

[57] In the description, an expression "comprising", "including" or "having" indicates the existence of a specific feature and does not exclude the existence of other features. The word "unit", "module" or the like may refer to a software component, hardware component, or a combination thereof capable of carrying out a function or an operation. When a component is connected or coupled to another component, it may indicate a physical connection, an electrical connection, or even a logical connection.

[58] In the description and claims, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[59] In the description, the word "user" may be, but not limited to, a wearer of a device, a user of the device, someone that passes and stands in front of a device, or a technician repairing the device.

[60] Hereinafter, various embodiments of the present invention are described in detail with reference to the accompanying drawings. The description of the various embodiments is to be construed as exemplary only and does not describe every possible instance of the present invention.

[61] Specific terms used in the embodiments of the present invention are provided to aid understanding of the present invention, and the use of such specific terminology may
be changed into other forms without departing from the subject matter of the present invention.

Terminology Definition>

FIG. 1 illustrates a model matching process according to an embodiment of the present invention.

Some terms to be used below are defined first. The term "device" means a set of sensor modules which can generate model data. The device can be a set of hardware modules, or it can also be software modules which consist of functions, conceptual modules, or programming objects processing model data. The term "system" means a set of connected things(hardware and software modules) or parts forming a complex related to process modeling or model matching. The term "model" means a set of two-dimensional (2D) or three-dimensional (3D) data generated for or about an object. That is, the system may generate digital data for an object (or target object) using one or more sensors, and store and manage the generated data as 2D or 3D data for the object. This set of data can be a model for the object. The term "6-DOF" represents free motion and orientation (i.e., unit vector or vector with a size or scale) or rotation (e.g., Yaw/Pitch/Roll) in a 3 dimensional space and may be represented by the movement in three-axis directions (e.g., x, y, z), and the orientation between the three axes (e.g., relative coordinate system with x-axis, y-axis, z-axis), or the rotation (e.g., roll/pitch/yaw or Euler angles). Or the 6-DOF also can represent a range of values which can have the free motion, the orientation, and the direction values in probability range. The term "2-DOF" or "3-DOF" have limited numbers of degree of freedom from 6-DOF. The 2-DOF can represent free motion in two dimensional space and the 3-DOF can represent free motion in two dimensional space and one rotation/direction which has an angle value. The 2-DOF and the 3-DOF can have a range of values or a probability range like the 6-DOF.

<sensing method introduction>

FIG. 2 illustrates various methods of model sensing by using sensors.

The system can generate data about an object 210 by transmitting optical signals of various wavelengths to the object and receiving reflected optical signals, and store the generated data, by using one or more sensors (222, 224). By way of example the transmitted wavelengths may be an infrared (IR), depth sensing frequencies, a laser lights, stereo cameras (more than one), IR cameras, IR through RGB spectrums and RGB cameras, which provide back different types of data describing the object. In addition, various methods such as Structured Light, Time of Flight, Stereo Pattern/Feature Matching, and the combination of the Structured Light/Time of Flight and one
or more than one sensor(s) using pattern/feature extraction method for 3D reconstruction, 3D feature extraction, and 3D model creation, LIDAR, speckle interference, and infrared proximity array can be utilized to collect data about an object.

[70] The system can also collect and store this data about an object for analysis, use, search, matching, 3D model creation and other functions. In addition, different types of data from different sources such as when one or more depth sensors and one or more biometric sensor(s) operate together, varied depth data can be merged to create 2D and 3D biometric data and models. That is, the sensor 1 (222) and the sensor 2(224) in FIG. 2 can be different types of sensor such as biometric sensor and depth sensor, thereby obtain different types of data by using different sources. By using a combination of different types of sensors, such as with depth and biometric sensors, model creation and search provides improved accuracy and speed.

[71] Also, the biometric sensor(s) could be utilized for depth sensing not only for 3d reconstruction of biometric data and 3D models, but also for transmission and reception of structured light or Time-of-Flight (TOF) to biometric objects by merging the depth data and biometric data together. The processing of merging the depth data and biometric data together could be conducted in a single domain or multi-domains. If the merging process uses single domain, the transmitted pattern (structured light reflection) can be processed to remove the pattern in the frame and the image could be re-used for biometric pattern extraction as well.

[72] This method can use one single frame or multiple frames from different devices, to conduct 2D pattern detection, stereo pattern detection or 3D pattern detection, 3D model creation, search and pattern removal (or pattern subtraction). These functions may happen by software or algorithms implemented or at the hardware level. When using multi-domain like one or more depth data and biometric data, a single model, combining these different data types creates a more well-defined and descriptive model. By way of illustration, when one or more RGB cameras or IR-RGB cameras are used with biometric sensors, then color data (2D or 3D) could be meshed on depth data (or 3D biometric data) in 3D space so that and multi-spectral models can be created. Further, the 2D or 3D RGB data can be subtracted from the 3D biometric image or pattern to improve biometric image quality. This is because IR spectrum may contain skin data and vein data and RGB spectrum may only contain skin data. By subtracting the RGB image to the IR image, better quality of biometric data could be obtained in 2D or 3D.

[73] <Model Structure / Model Surfaco

[74] As described above, the model may refer to two dimensional or three dimensional data, and the process for creating the model may be post-processing of digital data.
In the flowing description of FIG. 1, the object is depicted as the back of a hand but is not limited to the back of hand and may constitute vein patterns from any part of the body. The system may utilize one or more sensors of different types to collect data about the object 110 and generate a 3D model of that part of the body containing the veins. Here, the object 110 can be largely divided into the structure and the surface for understanding, and the structure and the surface are different representations of the organic object and can be combined to create a different view of object 110.

Specifically, the distribution 120 of the veins present inside the back of the hand being the object 110 may correspond to the structure of the model of the object 110. In particular, the veins are distributed in three dimensions (with all points represented in X, Y, Z space) inside the back of the hand, and this distribution can be understood by being divided into points, lines, networks, and areas. The specific procedure for analyzing the vein distribution or skin line (i.e., structure) will be described later.

The skin 130 constituting the outside portion of the back of the hand being the object 110 may correspond to the surface of the model of the object 110. Feature points 132, such as hairs, palm lines, fingerprints, wrinkles, bends, skin lines, nails and pores, located on the skin 130 may also constitute the surface of the model of the object 110 model together with the skin 130.

The structure and the surface constituting the object 110 move together according to the movement of the object 110. For example, when the hand is moved in the space, the structure and the surface are tracked and modeled together in the three-dimensional space. When the back of the hand is bent or rotated, the structure and the surface are moved or rotated accordingly in the space.

In detail, human body consists of living organism can cause a significant change when the living organism naturally works. That is, when blood circulation (blood vessel expansion), body skeleton position change, and/or even breathing works, skin stretches, skin color distributions, the human body moves and changes its position, rotation, and direction according to the natural works of the organism, then the 3D models created must also adapt but remain within the range of possible transfigurations, which ensure all operations described herein can still be accurately performed. The biometric object movements can be understood by the biometric structure and the surface changes and other data (depth, laser, RGB etc.).

Next, a description is given of an example for performing model matching by analyzing the movement and rotation(direction) of the structure and the surface. Here, model matching may refer to a process of comparing a model being analyzed to determine the sameness and/or similarity between the two models, or pieces of models, or swatches of models within other more complete models. Data models that are being compared may be a pre-stored model or any real-time time data stream or other repre-
sentation possible of 2D or 3D data or models. The main point is that two models are compared to build a 3D model based on these comparisons of different 2D or 3D data sources. In particular, a method for efficiently performing model matching even in an environment where the object 110 moves in real time in the space is proposed as an embodiment. The proposed method is based on the analysis of the structure and/or the surface described above.

[82] Extracting singularity point>

[83] FIG. 3 illustrates a structure analysis process in accordance with an embodiment of the present invention. The structure analysis process to be described below is based on the structure theory of veins. The structure theory indicates a way of interpreting a 3D vein structure in terms of point, line, network, attributes and area.

[84] To be more specific about the structure theory, the points may include a bifurcation point (302, 304, 306 in FIG. 3) or a singularity point that is easy to observe in the vein structure. A point that is easy to observe may mean that the intensity of the signal sensed by the device through a sensor is relatively large compared to other positions or that the point is recognized as the same point each time the object is observed from one or more units. A line refers to a straight line or curved line created by connecting two or more points (308 in FIG. 3). A network may refer to connected paths within a mesh of points. By connecting two points (302 and 306 in FIG. 3) selected from a plurality of points lines within the network are used to describe the 3D model of the biometric object being observed and modeled.

[85] The described features (Points, Lines, Networks, and Areas) and the orientation, and value(scale, or size) of the feature points vary by distance, rotation, direction, sensing angles, image scale changes. The biometric or pattern data may change continuously (e.g. blood expansion changes the shape or the network, location of points and brightness of lines in IR spectrums) and some feature extraction methods could be introduced to extract invariant and variant features from the bio-data. For example, invariant features for rotation and distance such as histogram of gradients, which lists gradients of neighbor points with a histogram, and variant features like bifurcation points, which differs by scale, may be extracted from the data set or model for accuracy of model or better performance during usage. The histogram of gradients could be used in 2D stereo matching and 3D model matching. When the histogram of gradients is used in 3D model matching case, the gradient vectors could be set to vertical to the normal of surface which the three directions or the three rotations of a 6-DOF make.

[86] The device, software application or algorithm performing model matching may analyze the structures between models based on this structure theory. First, as
described above, the device can see an object by utilizing one or more of various sensors. For example, the device may recognize an object (e.g., veins inside the back of a human hand) by transmitting an optical signal and sensing the reflected optical signal and generate structure data. Our analysis of this data is used by our unique modeling method to create a 3D representation of these objects for computational processes like unique identification and motion tracking.

The process of creating 3D models is one of transforming a point at a specific position of the vein structure into a three-dimensional position, and in relation to other observed points in the network. This process is repeatedly performed to get many positions for each point and dynamically create and adjust the model as the object is in motion. This forms a new asset we call the Motion Signature, which will be described and claimed later in this document. Based on the vein structure theory described above, this transformation process may be performed in sequence along the lines and networks for the whole vein structure to be identified and recreated in a 3D or 3D model. For example, the system may perform the transformation process for the position 302 in FIG. 3 and then perform the transformation process for the positions present along the line 308 to reach the point 306. When the vein structure for one line is identified, the structure analysis may proceed by comparing the lines between different models created by our algorithms or from different camera sources.

<Structure Analysis Process>

In the above description, the line comparison process is described as an example of structure analysis. However, the structure analysis is not limited to the process of comparing lines; the comparison process can also be performed in terms of network or area in the vein structure described above. The specific position (i.e., point) at which the transformation process for the vein structure begins may be a bifurcation point or a singularity point. However, the present invention is not limited thereto, and the transformation process may be initiated at any point in the structure data.

With reference to FIGS. 4 and 5, a description is given of basic concepts applied to the analysis of the structure and surface in model matching.

FIG. 4 depicts a 2-DOF (degree of freedom) extension process in accordance with an embodiment of the present invention. FIG. 5 depicts a 6-DOF extension process in accordance with an embodiment of the present invention.

<2-DOF stereo matching>

2-DOF matching process can be used for stereo feature/model matching or stereo points matching which compare 2-DOF data from multiple images to make 3D reconstruction data. This method can be performed with stereoscopic method or combination
of methods including stereoscopic approach. In case of using 3-DOF, a freedom of direction/rotation/angle between the first 2-DOF in the first image and the second 2-DOF in the second image could be added to the 3-DOF.

In FIG. 3, consider P1 (411) and P3 (413) first for model 1. P1 (411) is one of plural points arranged in two dimensions in model 1 and is separated from point P3 (413) of model 1 by $d_{x1}$ in the x-axis direction and $d_{y1}$ in the y-axis direction. Next, for P2 (412) and P4 (414) in model 2 different from model 1, P1 (411) is spaced apart from P2 (412) by $d_{x2}$ in the x-axis direction and $d_{y2}$ in the y-axis direction, and P1 (411) and P2 (412) are matched with each other. When P1 (411) and P3 (413) have 2-DOF, the displacement between P1 (411) and P2 (412) may be represented by $d_{x12}$ and $d_{y12}$, and the displacement between P3 (413) and P4 (414) may be represented by $d_{x34}$ and $d_{y34}$.

A probability theory may be applied with respect to FIG. 3. When points P1 (411) and P3 (413) having 2-DOF (x, y) in model 1 of a given object are matched with certain points at specific positions in model 2 to be compared, we cannot be sure about the exact position but we can assume that the solution exists within a certain range. For example, when the displacement between matching points P1 (411) and P2 (412) is represented by a 2-DOF difference ($d_{x}$, $d_{y}$), finding an accurate point with $d_{x}$ and $d_{y}$ values in a model pre-stored in the device or another model may correspond to finding the exact position (i.e., unique solution) described above.

On the other hand, based on the probability theory that determines the range in which the solution exists instead of the absolute solution with exact points; a point having a value in range 2 (422) specified based on a specific probability can be found instead of the displacement $d_{x}$ and $d_{y}$ between matching P1 (411) and P2 (412). Here, the accuracy of model matching considering such a range is determined by how wide or narrow the range is. In other words, minimizing the range will find the unique solution closer to absolute reality (with a probability of 100 percent) and widening the range will reduce the probability of having the exact solution. This method allows for accurate computational processes without perfect coordinates, so that the target solution is ensure to be within the range.

When the structure and surface data of model 1 correspond (within the defined range of variation) to the structure and surface of model 2 in two models being compared (model 1 and model 2), the position and direction (6-DOF) of all the data in model 1 can be a comparison reference, and the 6-DOF range (probability) value of each point relative to the comparison reference includes the position and direction value of data of model 2. Through various probability calculations, the probability values of the data of model 1 can converge to a specific value with the decreasing range. If the data of model 2 are included in the convergence range or probability, it can be said that the
two models being compared match each other. That is, the probability range of one point of model 1 may initially include all the points of model 2, and may correspond to one point of model 2 or have a probability of a convergence range after the matching ends successfully. Having a probability of a convergence range does not necessarily mean that it should include more than one point. This is because the object model may not accurately reflect actual data every time it is created. Our method allows for slight differences between difference devices to be reconciled into our output model for use within applications.

More specifically, in FIG. 4, when the 2-DOF values of P1 (411) and P3 (413) are known accurately and are accessible, the relationship between P3 (413) and P4 (414) can be analyzed based on probability theory. P2 (412) is in range 2 (422) in the relationship between P1 (411) and P2 (412), and the position of P4 (414) is separated from the position of P3 (413) by $d_{x34}$ and $d_{y34}$. Here, if the relationship between P3 (413) and P4 (414) has the same probabilistic elastic modulus as the relationship between P1 (411) and P2 (412), the displacement values ($d_{x13}$ and $d_{y13}$) between P1 and P3 can be converted into probabilistic values and added to already known range 2 (422) between P1 (411) and P2 (412). This result can be converted into a range value (range 4 (424)) of P4 (414) that can be matched with P3 (413).

That is, when the range of displacement values between P1 (411) and P2 (412) is known and the displacement values between P1 (411) and P3 (413) are known, the range of displacement values between P3 (413) and P4 (414) can be inferred or predicted by the device. The range of the displacement values ($d_{x34}$ and $d_{y34}$) approaches range 4 (424) in proportion to $d_{x13}$ and $d_{y13}$ from range 2 (422) between P1 (412) and P2 (412). More specifically, the x-axis value of $d_{x13}$ has an elastic modulus of $d_{x}$, and the y-axis value has an elastic modulus of $d_{y}$, and these correspond to an increase, decrease, or change in the x-axis probability range for $d_{x}$ and the y-axis probability range for $d_{y}$, respectively. Likewise, an elastic modulus of $d_{y-x}$ for the x-axis value of $d_{y13}$ and an elastic modulus of $d_{y-y}$ for the y-axis value may be translated into an increase, decrease, or change in the x-axis and y-axis probability ranges, respectively. When the x-axis probability range change amount ($d_{x13-x}$, $d_{y13-x}$) and the y-axis probability range change amount ($d_{y13-y}$, $d_{y13-y}$) described above are added to range 2 (422), the probability ranges of range 4 (424) is determined. Alternatively, when the 2-DOF displacement amount is integrated from P1 (411) to P3 (413) with respect to elastic moduli $d_{x-x}$, $d_{y-y}$, $d_{y-x}$ and $d_{y-y}$, and added to the probability range value of range 2 (422), the probability ranges of range 4 (424) may be obtained.

As described above, when a particular point in one model (model 1) is represented as a probability range in the corresponding model (model 2), the probability theory can be applied in sequence to adjacent points. If the probability theory is applied in sequence
to adjacent points, the matching result of one point will affect the DOF of the next point, resulting in a continuous effect that affects all DOF points of the compared models. The degree of this influence is determined based on the probability described above. This probability may be adjusted by the user, may be automatically determined according to the operation of an algorithm or program, or may be updated and managed in real time in consideration of an external environment or parameter.

As such, it is possible to specify the arrangement of plural points and positional relationship there between based on the probability. The advantage of this probability-based extension scheme in the model matching process is that it reduces the total number of cases by controlling the probability when the range that other nearby points can have is probabilistically determined from the DOF of a particular point. Different probabilities will be used based on usage needs for better accuracy and processing speed.

<6-DOF model matching with probability theory>

In FIG. 5, a description is given of a 6-DOF extension process based on the 2-DOF extension process described above with reference to FIG. 4. FIG. 5 shows an example in which probability computation based on the probability theory described above and is applied in the 6-DOF extension process.

The probability theory (or probability computation based on probability theory) applied to the 6-DOF to be described in FIG. 5, unlike FIG. 4, correspond to a computation procedure based on a range given in a 6-DOF space. For example, a position xyz in space can be defined within a cuboid range represented by 10<χ<20, 10<y<20 and 1000<ζ<1500, and this cuboid range is a numerical representation of the range that one cell can exist. Alternatively, the probability theory can be understood and be applied as the relationship between points that exist as probabilities within a continuous range based on Brownian motion, particle motion in quantum mechanics, or wave theory. By minimizing the radius of motion, it is possible to reduce the range of motion or vibration of the cell in the space, and the accurate position value can be obtained.

In this case, the direction from the origin in space to a given position xyz can be represented by Euler angles (yaw (vertical axis), pitch (lateral axis), roll (longitudinal axis)), Tait-Bryan angles, or an independent coordinate system (e.g., axisX, axisY, axisZ). The cases representing probabilities through Euler angles or Tait-Bryan angles may be divided into x-y-z, x-z-y, y-z-x, y-x-z, z-x-y, and z-y-z, which may then correspond to yaw, pitch, and roll. Probabilities can be represented by a range value between [-PI, PI] (i.e., -PI ~ PI), [-2PI, 0], [0, 2PI] for yaw/pitch/roll. In addition, axisX, axisY and axisZ can be separately represented by independent direction co-
ordinate systems, or represented mathematically by two or more combined coordinate systems.

In FIG. 5, the relationship between P1 (x1, y1, z1) (511) and P2 (x2, y2, z2) (512) is described first. It can be assumed based on the probability theory that the spatial position of P2 (512), one of the points that can be matched with P1 (511), is within a 3D candidate space (or 3D range). P1 (511) and P2 (512) can each be represented by a 6-DOF value with the position and direction (rotation) of three axes on a three-dimensional space. Then, a 6-DOF value (6DOF_l2) between P1 and P2 can be obtained by comparing the 6DOF value of P1 (511) with the 6-DOF value of P2 (512). This is a concept corresponding to the displacement value of 2-DOF described above with reference to FIG. 4, and can be defined by a position difference value (dx, dy, dz) in space and a value in the transformation coordinate system with three direction (rotation) axes. The three-axis transformation coordinate system can be obtained by transforming the three direction axes into a matrix and finding the corresponding transformation matrix. Here, the 6-DOF value (6DOF_l2) between P1 and P2 can be specified as a range value by applying the probability theory rather than one specific value. This is described in more detail later.

P3 (x3, y3, z3) (513) is located in the same model as P1 (511). Assuming that P4 (x4, y4, z4) (514) is one possibility of being matched with P3 (513), the probability range of P4 (514) may be specified by the 6-DOF range (524), and it can be said that P4 (514) belongs to this possibility. Here, the relationship between the relative 6-DOF value (6DOF_l2) between P1 and P2 and the relative 6-DOF value (6DOF_34) between P3 and P4 can be represented by 3D position and rotation based on the concept of probability similar to that of the 2-DOF case described before.

To sum up, 6DOF_l2 is related to 6-DOF value that transforms the 6-DOF value of P_x y z xAxis yAixs zAxis 1to the 6-DOF value of P_x2y2z2xAxis2yAxis2zAxis2, and 6DOF_34 is a relative 6-DOF value that transforms the 6-DOF value of P_x3y3z3xAxis3yAxis3zAxis3 to the 6-DOF value of P_x4y4z4xAxis4yAxis4zAxis4. However, this transformation is not a conversion into specific position and direction values but is a conversion into a probability range in a space including the accurate actual value. Here, the value of 6DOF_l2 and the probability of 6DOF_34 may interfere with each other or affect each other.

The 3 position axes and the 3 direction axes of the above 6-DOF probability can be calculated separately. If P1 (511) and P3 (513) are adjacent and the displacement of 6DOF_l2 between P1 (511) and P2 (512) is similar to the displacement of 6DOF_34 between P3 and P4, it is highly likely that the positions of P2 and P4 that can be matched therewith are adjacent to each other. Additionally, if the direction values of
P1 (511) and P3 (513) are similar and the direction values of 6DOF_l2 and 6DOF_34 are similar, the direction axis values of P2 and P4 that can be matched therewith may also be similar to each other.

When the 6-DOF values of P1 (511) and P3 (513) of the comparison model are known and the 6-DOF value (6DOF_l2) between P1 (511) and P2 (512) is represented as a probability, 6DOF_34 between P3 (513) and P4 (514) can be estimated. The value of 6DOF_34 can be predicted by applying the probability theory to the position difference between P1 (511) and P3 (513), the direction axis difference there between, or the difference in direction transformation matrix there between. Here, the probabilistic elastic modulus described above can be applied. The elastic modulus can be applied to the displacement for the distance or 3 position axes as a constant, as a value proportional to the first, second, or nth derivation, or as a value derived from other mathematical equations. The elastic modulus can also be used to calculate the amount of change in the direction vector for the displacement or distance of the position X/Y/Z axes or the amount of change in the rotation axes. The vector change amount of the direction vector (axisX, axisY, axisZ) or rotation (yaw, pitch, roll) for the displacement of the position X/Y/Z axes, or the amount of change in direction and rotation due to the change in angle or distance may be applied as a constant, or may be represented by a mathematical equation including the first, second, or nth derivation.

For example, when the displacement of the direction or rotation of P1 (511) or the amount of change in distance is known, it is possible to predict how the direction or rotation axis values change along the path from P1 (511) to P3 (513). The displacement or distance in the rate of change of directions or rotations may be a displacement based on a value in an absolute coordinate system, be a displacement based on a value in a relative coordinate system generated at the direction or rotation axis of the reference point, or a displacement based on a relative coordinate system for the direction or rotation transformation between the reference point and the matching point of another model being compared. In addition, the rate of change in direction or rotation may be a rate of change in direction or rotation in an absolute coordinate system, be a rate of change in direction or rotation in a relative coordinate system generated at the direction or rotation axis of the reference point, or be a rate of change in direction or rotation in a relative coordinate system for the direction or rotation between the reference point and the matching point of another model being compared. Such displacement or rate of change in direction or rotation along the distance may also be a probability range value, to which the above-described probability theory is applied.

Meanwhile, if the 6-DOF value between P2 (512) and P4 (514) is additionally known, it is possible to find the probability range of 6DOF_34 by considering all of
6DOF_l2, 6DOF_l3, and 6DOF_24. Since the device already knows the 6-DOF value of P3 (513), if the probability range of 6DOF_34 is found, the range value of 6DOF_4 can be found.

Hereinafter, a description is given of calculating the 6-DOF range value of P4 (514) from P1 (511), P2 (512) and P3 (513) by applying the probability theory. After finding P4 (514), this procedure may be extended in a similar way and applied to calculating the range value (526) of 6DOF_6, being the 6-DOF range of P6 (x6, y6, z6) (516), from P3 (513) and P5 (x5, y5, z5) (515).

In addition, the position and direction or rotation probabilities can be geometrically represented by using a given space figure preset, machine-learned, or contextually applicable. For example, for each of the X, Y, and Z axes, one direction axis can be independently represented as a volume or surface value in a sphere, cuboid, or more complex mathematically designed three-dimensional space. Then, the probability can be represented by applying mathematical inequalities to the surface or volume of such a figure. Alternatively, some or all of the three direction axes can be stored together in one geometric model. The geometric model stores a specific probability for a volume or surface, and can be used directly for probability operations to be described below.

One or more of operations such as initialization, expansion, subtraction, and multiplication may be applied in sequence or in combination to the probability represented in a manner described above. Initialization refers to the process of returning a geometric probability model by transforming a given initial direction value into a probability range.

When transferring a probability of the initialized probability model (i.e., representing a probability range value) to an adjacent cell, expansion refers to the process of geometrically expanding and returning the probability based on the elastic modulus of the cell with respect to the distance or displacement between adjacent cells, or based on the rate of change in direction or rotation with respect to the distance or displacement.

Subtraction refers to the process of identifying the intersection between the geometric model or range probability of the cell and the geometric model or range probability received from a neighbor cell and returning the intersection.

Multiplication refers to the process of converting displacement information of one model (existing as one range among the XYZ ranges on space) into displacement information of another model by multiplying the displacement between adjacent cells in the same geometric model and a matrix generated (i.e., transformed) by a direction or rotation value together. Here, the rate of change in direction or rotation with respect to the distance or displacement can be applied. As the direction or rotation axis changing with the displacement in model 1 is applied as matrix multiplication, the displacement in model 2 can be obtained more accurately.
Specifically, the matrix operations described above are a process of converting the direction or size for 3 direction or rotation axes of one cell into a 3x3 or 4x4 matrix or a probability matrix composed of variables having a probability range, and deriving a probability position by applying matrix operations to the displacement value (vector) between the cell and the adjacent cell. The probability theory described above (i.e., probability calculation based on the probability theory) can be applied between a given cell and its adjacent cell, which is represented by the influence of one cell on another cell. A similar approach can be applied to the 6-DOF probability operation for P_xlylzl, P_x2y2z2, P_x3y3z3, and P_x4y4z4, or to the relative 6-DOF probability operation therebetween.

Meanwhile, all the cells of model 1 can have the same probability elasticity (or, probabilistic elastic modulus) and the same rate of change in direction or rotation with respect to the distance or displacement, or have different probability elasticities (or, probabilistic elastic moduli) and different rates of change in direction or rotation. Each cell may also have a unique value. Each cell has a 6-DOF probability range absolutely or relatively to the neighbor cells. As such, for the relative 6-DOF value, which converts a cell of model 1 into a cell of model 2, the accuracy of probability calculations can be gradually increased by simulating model matching through pre-storing or machine learning. If the relative 6-DOF value is used within a given range, it can be used for tracking. Here, because the amount of change in position and rotation is limited over time, the solution is found within the limited range. In this case, the position and direction can be tracked for all the cells, which will be described later. This indicates that all components including feature points can be uniquely identified and stored with respect to the sensing model, and indicates that the change in direction or position of the surface can be learned for an absolute coordinate system, a relative coordinate system generated by the relationship between neighbor cells, or a relative coordinate system between cells of model 1 and model 2 being matched.

To sum up, in the case of assuming 6-DOF, it is also possible to determine the positional relationship and directional relationship in sequence for adjacent points based on the probability theory. When the probability-based method described above is applied in the model matching process for three-dimensional models, controlling the probability makes it possible to reduce the coordinates on the space that adjacent points can have. Hence, it is possible to reduce the computational complexity and time required for the entire calculation process. In particular, the 3D model of 6-DOF has a higher computational complexity than the 2D model, so the advantages of the proposed probability-based approach will be greater.

In FIGS. 4 and 5, a description is given of a probability based method for de-
terminating the position and coordinates of another point adjacent to one point. The method can be applied to both structure analysis and surface analysis for the model matching process described before. This is because both the structure analysis and the surface analysis are basically a process of comparing plural points of different models and producing a matching result.

[129] The structure data and surface data generated by the device may be two-dimensional data represented as a two-dimensional map, or may be three-dimensional data defined on a three-dimensional space. Alternatively, the 3D position surface information can be stored in a 2D map. In this case, the 2D information can be stored together with the 3D position information in a matching fashion.

[130] For structure or surface analysis, the device can extract features or feature points from 2D or 3D data. For example, the device can generate feature data from 2D data or 3D data by using intensity, surface normal, curvature, vein, skin line, and relationship between features. Such feature data can be generated as a rate of change in position or time. Specifically, the parameters utilized by the device are as follows: i) intensity first derivation, intensity second derivation, or intensity N-th derivation; ii) surface normal, or surface normal N-th derivation; iii) surface curvature, or surface curvature N-th derivation; and iv) line gradient (for a line extracted from the human body such as vein or skin), or line gradient N-th derivation (for a line extracted from the human body such as vein or skin). The device may use one or more of the above parameters to extract v) inter-feature relationship as feature data. Alternatively, if the device is observing the structure or surface of the object, the device may extract features with respect to a change in spatial position, rotation, direction and time from signal strength, surface, structural dynamics, human body feature information, and inter-feature relationships. Since the information thus generated includes position and direction (vector) information, the 6 DOF necessary for model matching can be generated. When matching the 6 DOF of model 1 with the 6 DOF of model 2, the device can produce a higher matching similarity by comparing feature information for each point. Here, in the case of using the relative 6 DOF that transforms model 1 to model 2, the device can transform the vector of a feature of model 1 to model 2 to thereby obtain the vector of the feature of model 2 and the similarity.

[132] FIG. 6 illustrates a surface analysis process in accordance with an embodiment of the present invention. The proposed surface analysis process is based on the polymorphic theory. The polymorphic theory is a concept that, under the assumption that the points on the surface of an object is an elastic body having elasticity, the surface changes in
accordance with the motion of the object and the amount of change is affected by adjacent points.

The plane shown in FIG. 6 is a two-dimensional representation of the surface of a two-dimensional or three-dimensional object. This is because the surface of a three-dimensional object can also be represented in two dimensions at a specific point in time. In the plane shown in FIG. 6, the points constituting the surface influence each other and are influenced by each other. For example, the 6-DOF value for point 610 may be calculated according to the embodiment described above, and this value may refer to the 6-DOF value of point 610 itself or the 6-DOF value between point 610 and the point matching point 610. This calculation result affects the calculation of 6-DOF values for adjacent points 612 and 614 according to the probability theory described in FIG. 3. Next, the 6-DOF value calculated at points 612 and 614 affects the calculation of the 6-DOF value of another adjacent point 616. In other words, the 6-DOF value calculated for a given point (e.g., point 616) at a particular position is affected by the calculation results of adjacent points. The degree of influence will be determined based on a specific probability as if there is an elastic modulus between the points constituting the surface. This probability corresponds to the probability theory described above in FIG. 3.

Likewise, the 6-DOF value calculated at point 620 affects points 622 and 624, and the 6-DOF values calculated at points 622 and 624 affect the 6-DOF calculation of point 626. This calculation process is performed in sequence for all the points constituting the surface data while influencing adjacent points like a wave. Thus, the points located at the center of the surface data are more and more influenced by the computation results of surrounding points. As these points must simultaneously satisfy the effects transferred via various paths, the 6-DOF computation process can rapidly reach a limited conclusion. That is, as the 6-DOF calculation process proceeds for the entire surface data, the computation will gradually become faster. This process of calculating the surface data can be applied to the process of finding the position, direction, and rotation in the structure data. More specifically, when the above method is applied to the structure data, the probability range of one point determines the probability range of an adjacent point within the range of a point, line, network, and area. For example, when a line of model 1 is compared with a line of model 2, if a point of the line of model 1 is matched with a point of model 2, this calculation result affects the probability range calculation for adjacent points belonging to the lines being analyzed.

Meanwhile, the 6-DOF calculation process for the surface data can be understood as a process of performing model matching by comparing the surface data of different models similarly to the structure analysis process described above. That is, for each point constituting the surface data, the 6-DOF value is calculated and compared to the
6-DOF value of another model to check if the two points are matched. If the 6-DOF values of two points are aligned side-by-side, it can be determined that the two points are matched. If one point is matched, whether another adjacent point is matched is determined based on the polymorphic theory and the probability theory described before, and this calculation process is performed in sequence on the entire surface data.

When the object is the back of a hand, as the back of the hand is bent or rotated, the surface data of one model may not substantially correspond to the surface data of another model. To cope with such a case, the system performing model matching can extend some surface data to create a virtual surface, and such an extension process can be performed based on the probability theory. Since the structure and the surface combine to form a model, the structure corresponding to the extended surface also needs to be generated. Accordingly, the device may extend the structure data to generate a virtual structure together. By use of the extended structure data and surface data, a sufficient number of data sets can be obtained for performing model matching.

FIG. 7 illustrates dynamic equilibrium in the surface analysis process in accordance with an embodiment of the present invention.

As the surface analysis process described above is performed, the surface data is matched and all the data are compared, leaving no additional comparison. Here, to explain the basic concept, it is assumed that the object is fixed although the object may move continuously in real time and the surface data may change dynamically. After completing the calculation for all the surface data collected by the device, points 710, 712, 714, 716 and 718 no longer affect each other. This state is called dynamic equilibrium. The dynamic equilibrium is a state in which the calculation is completed for the influence in consideration of the elastic modulus between the adjacent points or the rate of change in direction and rotation. On the other hand, reaching the dynamic equilibrium state may not necessarily mean that the model matching has been successful. That is, the dynamic equilibrium state means that the analysis of surface data for given matching data is completed, but the result does not guarantee that the matching with another model is successful. It may also be understood that dynamic equilibrium is a state in which the effects of all points on a given point are completely calculated. Every point affects adjacent points. Such a chain effect may indicate that the probability influence of a distant point is delivered to a given point through chain point probability calculation.

In addition, when new surface data is generated owing to an additional matching or time-based motion occurring at a different position of the object while the dynamic equilibrium is maintained, the dynamic equilibrium is no longer maintained and a new analysis process will be performed based on the updated surface data. Here, the elastic modulus between adjacent points will not suddenly increase or decrease exponentially,
and the object will not change its shape in an infinitesimal instant. Hence, once the
dynamic equilibrium state has been reached, it can be expected that a subsequent
change of the object falls within a preset threshold range, and the device may analyze
the updated surface data in consideration of such information.

Hereinabove, a description is given of an embodiment for performing model
matching through structure analysis and surface analysis based on the concepts of
probability theory, structure theory, polymorphic theory, and 6-DOF. Next, a model
matching method is described in a time series manner with reference to FIGS. 8 and 9.
Here, since the embodiments described below operate on the basis of the embodiments
described before, the descriptions in FIGS. 1 to 6 may be applied in an identical or
similar way even if a detailed description is omitted.

FIG. 8 is a flowchart of a model matching method in accordance with an emb-
diment of the present invention. First, the device performs object modeling (810).
Object modeling refers to a process of generating two-dimensional or three-dimen-
sional data of an object and storing the generated 2D or 3D data. The device or
system can collect data about an object by using one or more of various sensors to
perform modeling of the object. For example, the device can generate data on the
surface of the back of the hand by imaging the back of the hand or sending and
receiving optical signals and can generate vein structure data. Since modeling is a
concept including both the structure and the surface as described earlier, performing
object modeling can include both data processing for the structure and data processing
for the surface.

The device or system can store and manage data of the object modeled at a specific
point in time. The object model managed by the device can be compared with another
model. Since the device can perform object modeling in real time, the model generated
using data collected at a specific moment can be compared with a model stored and
managed in advance.

A detailed description is given of the process by which the device performs model
matching. First, the device performs an analysis of the structure among the structure
and the surface constituting the model (820). This order is for convenience of de-
scription. In the model matching process, surface analysis may be performed first, or
structure analysis and surface analysis may be simultaneously performed.

The system analyzes the structure of the model to be compared and the structure of
the target model, and the structure theory and probability theory described above can
be applied to this analysis process. That is, the system may calculate 6-DOF values for
a plurality of points constituting the structure data and find a relative 6-DOF value or a
matching point by comparing the 6-DOF values with the corresponding 6-DOF values of another model. At this time, the device may form a line with priority given to a bifurcation point or a feature point among a plurality of points on the basis of the structure theory, and can continue the analysis process toward another point. In addition, when calculating the 6-DOF value or relative 6-DOF value for the adjacent point during the analysis process, the device can specify a probability range that can be derived from the calculation result of the previous point on the basis of the probability theory. This probability-based approach may reduce the computational complexity and the amount of computation required to compare all points in a 1:1 fashion.

Upon determining that a structure matching is found between the two models through the structure analysis process, the device then performs the surface analysis process (830). In the case of a model whose structure analysis is completed, the 6-DOF values or the relative 6-DOF values of the points constituting the structure can be reflected, and the surface analysis is likely to proceed successfully. Hence, the device performs the surface analysis on the model whose structure analysis is completed. The polymorphic theory and the probability theory described before can be applied to this analysis process. The device computes 6-DOF values for a plurality of points constituting the surface data and compares them with 6-DOF values of the other model to find the matching points. Here, the device applies the probability (i.e., range) value, which has been applied to calculating 6-DOF values in the structure analysis, to the surface analysis. As described above, this is because, in the case of the model whose structure analysis is completed, the surface analysis is likely to be completed. However, the device may also use a probability value for the surface analysis different from the probability value used for the structure analysis. The surface analysis process may be performed in sequence while adjacent points mutually affect each other as described before with reference to FIG. 5.

Upon completing the surface analysis, the device examines the result of comparison with the stored model (840). If the structure analysis and surface analysis are successfully completed, the device can determine that a matching is achieved between the model to be compared and the target model. Here, if the object being compared has been moved, the structure data and the surface data are updated and the comparison is not finished. In this case, the device can perform the process of object modeling, structure analysis, and surface analysis again (850).

Although not shown in FIG. 8, the device may apply scaling in the structure analysis and surface analysis. Here, scaling means that matching is performed not on all of the structure data and the surface data but on partially extracted candidate data. On the other hand, scaling also can be conducted by performing the matching with blurred image data (2D, or 3D). For example, Gaussian blur could be used and it can have
similar/same effect as partial candidate data extraction. Specifically, the device may extract some data (e.g., 1/2, 1/4, 1/8, 1/16) from all of the structure data and the surface data, and perform structure analysis and surface analysis for the extracted data only. The device may extract some number of pixels (e.g., resolutions) from all of the pixels of a data, instead of extracting the data. This scaling scheme has the advantage of reducing the calculation time in that it reduces the number of points to be model-matched. The reliability of the scaling result may be reduced compared to when scaling is not applied. However, the device can adjust the probability value or compensate for the 6-DOF values in the matching process using the extracted candidate data so that the result value can have sufficient reliability.

When structure matching and surface matching are completed for the scaling result from the limited data, the probability value of the completed data can be transferred to the scaled-up data. For example, if the inter-model probability range for the 1/l6-scale cell data of the structure and surface data is sufficiently narrowed, the resultant probability range can be transferred to the 1/8-scale cell data. The 1/8-scale cells have more data including 1/l6-scale cells. The probability range of a 1/8-scale cell may be calculated by adding the error due to the scale increase to the probability range of the corresponding 1/l6-scale cell. This probability scaling technique can be used to obtain a large-scale probability range with a small amount of computation.

FIG. 9 is a flowchart of a model matching method in accordance with an embodiment of the present invention. FIG. 9 illustrates another embodiment of the model matching method that can be carried out in conjunction with the embodiment described in FIG. 8.

The device performs object modeling (910). The device compares the model to be compared with the target model by analyzing the structure and the surface constituting the object model (920, 930). On the other hand, since the model matching is performed in real time, the object can move or be moved during this model matching process. Accordingly, if the device detects a change of the model due to movement of the object (980), the device may collect data about the changed model and update the structure data and the surface data (990). The device may collect data about the dynamically changing model and perform model matching in real time. The device may continue model matching until the comparison is ended (940).

Meanwhile, upon determining that the dynamic equilibrium state has been reached or sufficient model matching has been achieved even though the dynamic equilibrium state has not been reached, the device checks whether the number of successful comparison results among the entire data for the matching with another model is greater than or equal to a threshold (950). If the probability ranges of the 6-DOF value or relative 6-DOF value of a point on the surface and structure converges or is less than
or equal to the threshold, the point can be regarded as a matching point. If the number of results from matching between the two models is greater than or equal to the threshold, as the two models can be regarded as identical, the device determines that the model matching has been successfully performed and the authentication is successful (960). If the number of results from matching between the two models is less than the threshold, the device may determine that the two models are not the same and determine that the authentication based on model matching is unsuccessful (970). If the two models are not identical, the dynamic equilibrium described above may not occur or the results of the probability calculations between points may not match each other. For example, the probability influence of all other points on a given point can be calculated, and the probability common denominator for the influence of each point may not exist. If there is a contradiction in the probability calculation, the degree to which the probability calculation differs from or is inconsistent with the dynamic equilibrium state can be measured numerically, which can be a criterion for determining the discrepancy between the two models.

[156] The model matching method described above can generate models including data about the vein structure and the skin surface, compare the structures in the matching between the generated models, and compare the surfaces probabilistically, thereby improving the speed and accuracy of the model matching. This matching technique can be applied to the process of tracking and authenticating some or all of the human body including the hand or face. In addition, through this matching technique, facial expression detection, emotional change detection, and human health monitoring can be performed. Further, it is possible to provide various biometric data, 6-DOF data of the human body surface, and a 3D human body model.

[157] FIG. 10 shows flowcharts of a model matching with stereo biometric sensing and depth biometric sensing. As described above and shown in FIG. 10, model sensing can be performed by using different types of sensors. The system can perform imaging process (1010) with sensors for biometric sensing (i.e., stereo biometric sensing); thereby obtain two or more images. Here, the system can also perform another imaging process with at least one sensor for biometric sensing and at least one sensor for depth sensing.

[158] The system can extract feature points (1020) from the plurality of images 1, 2, 3, 4 to generate 2D structure/surface data for each of the images. The system can also process the image 4, which is obtained by depth sensor, by removing depth structured light pattern from the image. And, the system matches the extracted feature points to create a 3D model (1030, 1040). The system can utilize the depth data by merging the depth data from image 4 to create 2D or 3D biometric model (model 1). The system can create another 3D model (model 2) by repeating the above procedures, and match a
The matching techniques could also recognize the 6-DOF in/of the structure and the surface as unique elements which have their own characteristics and features and could identify/monitor them in a duration of time (6-DOF continuous authentication or 6-DOF tracking). The sequence of the 6-DOF changes in a time period creates a motion signature of the 6-DOF of the biometric model (vein pattern). In this process, any changes or motion from body movements generate unique biometric data which reflects human skeleton, skin, vein, and other biometric components' dynamics. Like the biometric data, the motion data of the biometrics is also identical to each other.

The vein motion signature (or the biometric motion signature) could be used for a creation and a matching of a motion model. The motion model maybe a time series data which the 6-DOF data, the structure data, or the surface data should (could) be located in a designed matter, such as positions and rotation (orientation) time-sequentially. The motion model matching may be a process that compares two motion models by performing the model matching techniques from the first motion model to the second motion model, which are time series 6-DOF changes recorded or machined-learned, or consists of a sequence of the models.

The biometric motion modeling method could be used for user identification, user activity authorization, money transaction, and any other credit required activities. This method may offer an extremely high level of biometric copy protection and could be reproduced repeatedly by users.

FIG. 11 shows flowcharts of a motion model matching in accordance with embodiments of the present invention. After creating a 3D model (1110) as described in FIG. 10, the system can monitor the 3D model for a duration of time to create a motion signature (i.e., motion modeling, 1120). The sequential 6-DOF changes of the 3D model can be represented as a motion signature of the biometric 3D model. The motion model matching (1130) can be performed by comparing two motion models according to the model matching techniques from the first motion model to the second motion model, which are time series 6-DOF changes recorded or machined-learned, or consists of a sequence of the models, as said before.

FIG. 12 illustrates an example of motion modeling in accordance with an embodiment of the present invention. Image 1210 of the FIG. 12 shows an obtained biometric image of an object. Image 1220 shows the motion signature obtained by monitoring the 3D model for a time period. Lastly, the image 1230 shows featured points extracted from the image 1210.
FIG. 13 is a block diagram of a system (or, a device) performing model matching in accordance with an embodiment of the present invention. In one embodiment, the device 1310 may include a sensor unit 1320, an input unit 1330, a control unit 1340, an output unit 1350, and a communication unit 1360. However, the configuration shown in FIG. 13 is merely an example, and a new component may be added to the shown configuration or an existing component may be omitted from the shown configuration.

The device 1310 may utilize the components shown in FIG. 13 to perform model matching as described before in connection with FIGS. 1 to 8. Specifically, the sensor unit 1320 can generate structure data and surface data of the object by utilizing one or more sensors of different types. The sensor unit 1320 may include multiple sensors operating based on different principles to collect data. Alternatively, the sensor unit 1320 may obtain the same result through post-processing of the data collected via one sensor.

The input unit 1330 receives a user input from outside the device 1310. For example, the input unit 1330 may include a user interface for sensing input from the user of the device 1310. The output unit 1350 outputs the results of processing performed by the device 1310 to the outside in various ways such as visual, auditory, and tactile senses. For example, the output unit 1350 may include a display and a speaker. The communication unit 1360 may connect the device 1310 with an external device, a server, or a network, and may include a wireless communication module and a wired communication module.

The control unit 1340 generally controls the components of the device 1310 to perform model matching according to the above-described embodiments. For example, the control unit 1340 may perform the structure analysis and surface analysis based on the model data collected by the sensor unit 1320, may reflect the value received through the input unit 1330 in the analysis process, may output the analysis result to the outside through the output unit 1350, or may transmit the analysis result to another device or server through the communication unit 1360.

Meanwhile, the model matching method described above can be implemented as a program (or code) that can be executed by a computer, can be stored in a computer-readable storage medium, and can be carried out by a computer system that decodes the program. Further, the data structure used by the above-described method can be recorded on the computer-readable recording medium through various means. The storage media in which the program or code for carrying out various methods of the present invention can be stored may include a ROM (read only memory), a RAM (random access memory), a CD-ROM, a DVD, a magnetic tape, a floppy disk, a hard disk, and an optical storage device. The program stored in a computer-readable storage
medium may be stored and managed by a computer system connected via the network in a distributed manner, and may be stored and executed as computer-readable code in a distributed manner.

[173] Hereinabove, various embodiments of the present invention have been shown and described for the purpose of illustration without limiting the subject matter of the present invention. It should be understood by those skilled in the art that many variations and modifications of the method and apparatus described herein will still fall within the spirit and scope of the present invention as defined in the appended claims and their equivalents.
Claims

[Claim 1] A method for a system to perform 3D model creation and matching, the method comprising:
generating a first model for an object utilizing one or more sensors;
calculating the 6 degree of freedom (6-DOF) value of a first point located on the first model;
comparing the 6-DOF value of the first point with the 6-DOF value of a second point that is located in a second model being compared with the first model and matches the first point; and
applying the comparison result to a third point adjacent to the first point in the first model, and determining the probability range of a fourth point that is located in the second model and matches the third point.

[Claim 2] The method of claim 1, wherein the probability range is a numerical representation of a cell in which the fourth point may exist in space.

[Claim 3] The method of claim 1, wherein the 6-DOF value is a value or a range of value indicating at least one of the movement, orientation, and rotation of a specific point in space.

[Claim 4] The method of claim 1, wherein the determining comprises determining the probability range by reflecting the elastic modulus between the first point and the third point in the comparison result.

[Claim 5] The method of claim 1, wherein the applying comprises calculating at least one of a rate of change in a direction or a rotation of a position displacement between the first point and the third point.

[Claim 6] The method of claim 5, wherein the applying further comprises:
applying the direction or the rotation of the position displacement between the first point and the third point, to a transformation matrix defined for the first model and the second model; and
obtaining a direction or a rotation of a position displacement between the second point and the fourth point, from the transformation matrix.

[Claim 7] The method of claim 5, wherein the direction, the rotation and the position displacement are values based on an absolute coordinate system, a relative coordinate system generated based on the axis of a reference point, or a relative coordinate system resulting from transformation between two matching points.

[Claim 8] The method of claim 1, wherein the applying comprises geometrically representing the probability for the position, rotation or direction based on a given space figure.
[Claim 9] The method of claim 1, wherein the model matching between the first model and the second model is applied to at least one of a process of comparing structure data of the object and a process of comparing surface data of the object.

[Claim 10] The method of claim 9, wherein the method further comprises determining whether the first model and the second model are matched, and wherein the determining comprises determining that the first model and the second model are matched with each other if the comparison result of the structure data and the comparison result of the surface data are above or equal to a threshold value.

[Claim 11] The method of claim 10, wherein, upon determining that the first model and the second model are matched with each other, the comparison result of the structure data and the comparison result of the surface data are transferred to scaled-up data.

[Claim 12] The method of claim 9, wherein the method further comprises extracting feature data from the structure data and the surface data, and wherein the feature data is generated by utilizing at least one of the intensity, color, surface normal, curvature, vein, skin line, and relationship between features for a particular point.

[Claim 13] The method of claim 9, wherein the structure data is data about the vein distribution of the object and the surface data is data about the skin of the object, and wherein the structure data and the surface data are two-dimensional data or three-dimensional data.

[Claim 14] The method of claim 1, wherein, if the data constituting the first model is changed before determining whether the first model is matched with the second model, the changed data of the first model is compared with the data of the second model.

[Claim 15] The method of claim 1, wherein the method further comprises: tracking a change of the 6-DOF value of the first point and a change of the 6-DOF value of the second point for a duration of time; and generating a motion signature for the first model and the second model respectively, by using the change of the 6-DOF values.

[Claim 16] A system capable of performing 3D model creation and matching, comprising: a sensor unit configured to obtain data about an object; and a controller configured to match two models based on the data obtained
through the sensor unit,
wherein the controller is configured to generate a first model for an
object utilizing one or more sensors of the sensor unit, calculate the 6
degree of freedom (6-DOF) value of a first point located on the first
model, compare the 6-DOF value of the first point with the 6-DOF
value of a second point that is located in a second model being
compared with the first model and matches the first point, and apply the
comparison result to a third point adjacent to the first point in the first
model to determine the probability range of a fourth point that is
located in the second model and matches the third point.

[Claim 17] A computer-readable storage medium storing a method for a system to
perform 3D model creation and matching, wherein the method
comprises:
    generating a first model for an object utilizing one or more sensors;
    calculating a 6 degree of freedom (6-DOF) value of a first point located
on the first model;
    comparing the 6-DOF value of the first point with the 6-DOF value of a
second point that is located in a second model being compared with the
first model and matches the first point; and
    applying the comparison result to a third point adjacent to the first point
in the first model, and determining the probability range of a fourth
point that is located in the second model and matches the third point.
[Fig. 8]

START

perform object modelling

perform structure analysis

perform surface analysis

compare with stored model

end of comparison?

YES

END

NO
A. CLASSIFICATION OF SUBJECT MATTER
G06K 9/00(2006.01)i, G06K 9/48(2006.01)i, G06K 9/62(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06K 9/00; G06K 9/62; G06Q 2040; H04N 7/18; G06K 9/48

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic database consulted during the international search (name of database and, where practicable, search terms used)
eKOMPASS(KIPO) internal & Keywords: user authentication, 3D, model, match, point, 6DOF value, comparison, probability range

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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