International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:9, No:7, 2015

Applying Kinect on the Development of a Customized 3D Mannequin

Shih-Wen Hsiao, Rong-Qi Chen

***Abstract*—**In the field of fashion design, 3D Mannequin is a kind of assisting tool which could rapidly realize the design concepts. While the concept of 3D Mannequin is applied to the computer added fashion design, it will connect with the development and the application of design platform and system. Thus, the situation mentioned above revealed a truth that it is very critical to develop a module of 3D Mannequin which would correspond with the necessity of fashion design. This research proposes a concrete plan that developing and constructing a system of 3D Mannequin with Kinect. In the content, ergonomic measurements of objective human features could be attained real-time through the implement with depth camera of Kinect, and then the mesh morphing can be implemented through transformed the locations of the control-points on the model by inputting those ergonomic data to get an exclusive 3D mannequin model. In the proposed methodology, after the scanned points from the Kinect are revised for accuracy and smoothening, a complete human feature would be reconstructed by the ICP algorithm with the method of image processing. Also, the objective human feature could be recognized to analyze and get real measurements. Furthermore, the data of ergonomic measurements could be applied to shape morphing for the division of 3D Mannequin reconstructed by feature curves. Due to a standardized and customer-oriented 3D Mannequin would be generated by the implement of subdivision, the research could be applied to the fashion design or the presentation and display of 3D virtual clothes. In order to examine the practicality of research structure, a system of 3D Mannequin would be constructed with JAVA program in this study. Through the revision of experiments the practicability-contained research result would come out.

***Keywords*—**3D Mannequin, kinect scanner, interactive closest point, shape morphing, subdivision.

I. Introduction

FASHION design is an industry closely connected to our lives. When a designer proposes a variety of design ideas, determining how to specifically present these ideas is an important consideration. Currently there are two methods used in the development of apparel products: one is plane cutting, and the other is three-dimensional cutting. In methods based on plane cutting, the basic pieces required for fashion design are generated by mannequin forms, and patterning is performed through adjusting the scale of the shaped cutting pieces. By contrast, in three-dimensional cutting, designers directly come up with the garment designs on the mannequin to obtain the shaped cuttings of the 2D pieces required for production. Therefore, no matter which method is adopted for fashion design and development, all of the mannequin used by the design profession are important media (Fig. 1 (a)) for the concretization of design ideas (Fig. 1 (b)); more specifically, the process is not only closely related to garment wearing fitness, but also affects the final appearance.

S.W. Hsiao is with the Department of Industrial Design, National Cheng Kung University, Tainan 70101, Taiwan (Tel: +886 6 2757575x54330; fax: +886 6 2746088; e-mail: swhsiao@mail.ncku.edu.tw).

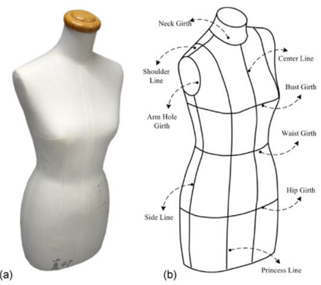


Fig. 1 Mannequin. (a) Professional mannequin; and, (b) the application of feature curves and aided curves

When applying the concept of mannequin to computer-aided fashion design, 3D mannequin links the development and application of the entire design system, thus rendering the 3D mannequin data required for fashion design appears very important.

Therefore, reverse engineering methods can be utilized for surface reconstruction of 3D mannequin based on feature curves (Fig. 2 (a)). By using a non-contact scanner to record the 3D point data of the mannequin used in design profession and intergraded various feature curves defined in the fashion design to the 3D mannequin reconstruction, different functions of 3D mannequin can be obtained (Figs. 2 (b), (c)). This brings advantages of the study in computer-aided fashion design in three aspects, which are first, apparels production from the construction of fashion design, enhancement in the feasibility and the need of the customers.

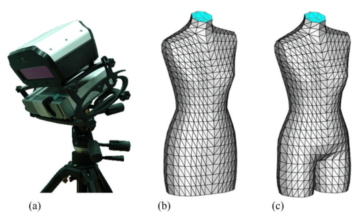
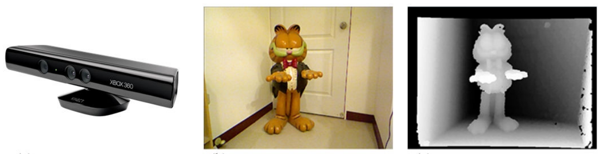


Fig. 2 Applying reverse engineering methods to reconstruct the 3D mannequin based on feature curves. (a) Non-contact scanner; (b) 3D mannequin for skirt design; and, (c) 3D mannequin for trousers design

On the other hand, the selection of mannequin is an important step in the process of apparel product development. Human factors for instance, age, gender, races working style represent different shapes and sizes of mannequins.

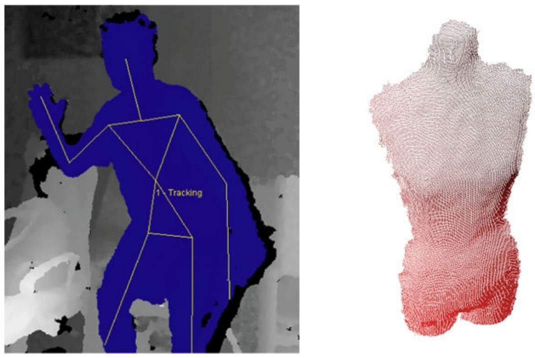
Furthermore, people with similar mannequins do not equal to people that share similar size. This further adds the complexity of mannequin design. Most of the fashion brands define standard mannequin model based on the size of different groups of the consumers as a criteria for the selection of mannequin. However, this kind of mannequin is generalized, larger sized mannequins is used to accord with the majority of the customers with comfort in wear. As the fashion brands approach personalization and customization, a more precise definition of sizes is required. Hence, how to obtain a more explicit mannequin of the customer is a big challenge. Thus, most of the fashion brands define standard mannequin model based on consumer-related data and developed distinctive mannequins of different sizes. This creates the unique features of each individual brands. Once the problems mentioned above are solved, the apparel product development can then be quickly and specifically presented in details and benefits the production process. This study proposed solutions to solve these problems. Moreover, in order to pursue a more authentic experience between human computer interaction, Microsoft launched Kinect (Fig. 3 (a)), a motion sensing input device. This device enhances video games to interact installation levels based on two cameras on the sensing device, general cameras and depth cameras which generates different data forms, colorful images (Fig. 3 (b)) and depth images (Fig. 3 (c)) respectively. Among the two cameras, depth images obtained from depth cameras are able to enhance the application of general cameras. Owing to the reason that with the assistance of AI of the OpenNI, the motion of users can be tracked (Fig. 4 (a). Therefore, the intention of hand gestures and body motions can be analyzed, and finally interact with the system and obtain a more direct operational mode. This shortens the distance between users and the system and accord with the goal of the study in human-computer interaction. Meanwhile, Kinect can be further applied as 3D scanners (Fig. 4 (b)) to scan the appearance of the object immediately. This can be viewed as a possible aspect in the development of shape reconstruction. When the sensing device is applied to the construction of 3D mannequins, not only the interaction of operational mode can be received, but also can be utilized between mannequins in actual scanning to get customization of 3D mannequins.



(a) (b) (c)

Fig. 3 Kinect motion sensing input device and the obtained data types. (a) Kinect motion sensing input device; (b) colorful images; and, (c) depth images

The study proposed the idea of applying kinect to the research and construction of 3D mannequins. In the current study, the main focus is to apply Kinect to scan mannequins.



(a) (b)

Fig. 4 The main application of Kinect motion sensing input device. (a) Motion tracking; and, (b) 3D scanning

First, Kinect sensing device is used to scan the appearance of mannequins, and obtain the depth information through API which is offered by OpenNI. The inofrmation then is converted to calculate each Pixel of the 3D position and thus reach a surface scan. A complete scan in appearance repeated the steps mentioned above in order to get different surfaces of the object. Then, based on the shapes of different surfaces, ICP (Internation Closest Points Algorithm) is used. After the interactive method used in ICP, a smaller error function will be obtained along with the result of superposition principle. However, in addition to depth information, the content of colorful images can also be produced when applying Kinect sensing device to 3D scanning. This can be integraded into 3D scanning positions, followed by the usage of digital image processing method. The method searches image features from the colorful image and constructs the coorespondent features. Hence, a more precice scanning spot registration will be obtained. After the shape reconstruction, measurements of the mannequins can be calculated through the registration of the feature detection algorithm and it can be aplied to 3D mannequin shape morphing. Thus, modules for 3D mannequin scanners can be genereated. In order to examine the feasibility of the proposed method, the study used JAVA to construct the 3D mannequin system and through performance correction, a practical result of the investigation can be reached.

II. Literature Review

The study of "Applying Kinect on the Development of a Customized 3D Mannequin System" proposed here owing to the reason that 3D mannequin plays an important role in computer-aided fashion design. There is ample space for creativity in all of the design, manufacture, display and performance links of the industry. However, during the process, determining how to obtain the required mannequin is a problem that cannot be ignored. Using reverse engineering methods to scan the mannequins required for fashion design is the most common solution [1]-[3]. The whole mannequin model can be reconstructed based on semantic features and parametric surfaces, and then the shape surface can be unfolded to obtain the 2D pieces required by plane cutting techniques, which is an important function of 3D mannequin [4], [5]. However, if the appearance of a human body can be directly scanned [6], [7], not only would the measurement results of individual sizes be obtained, but the parametric design based on the statistical data could also be carried out to obtain the respective 3D mannequin for any size [8]. Although attaining the proper grouping of, and reconstruction from, the scanned data according to features are major challenges in the process, drawing on the 3D mannequin to generate 3D virtual clothing can unleash the advantages of computer-aided design to achieve product development using synchronous design methods [9]. This is also the goal that has been jointly sought by many related studies, especially studies on how to enable computer-aided fashion design to better fit design practices [10].

However, for fashion brands of small and medium enterprise, application of computer-aided fashion design in 3D virtual mannequin scanning becomes one of the burdens. Regardless of the application of virtually try-on apparel and display, how to retrieve body sizes of the customers is another difficulty. Therefore, even though there exists body scanner, it is hard to apply in public. Nonetheless, when Microsoft launched Kinect sensing device, owing to the unique depth computation, the 3D position data of the scanned object can be obtained through converting. This can be applied to body motion recognition and track the 3D data immediately without complex image processing [11], [12]. Furthermore, it can also be used in the study of 3D scanning and reconstruction and offer a low-cost solution for 3D scanning [13], [14]. Notwithstanding, this kind of technology generates the problem of noise points [15]. A common methodology is to apply ICP for registration in data scanning about different scanning positions [16], [17]. However, the search for the mutual features in order to establish the one to one relationship in algorithm is the main focus of the area of the study [18]. These can be solved when applying Kinect as a 3D scanner in view of the camera on the sensing device is able to record color images of the whole process. This enables researchers to recognize labeled features among the color images by using image processing method [19]. Thus, one to one relationship among different scanning positions can be established and enhances the accuracy of the ICP algorithms results. Through the integration and correction in these methods, applying Kinect sensing device to 3D body scanning becomes possible. After each feature is being measured, the measurement can be implemented to the previous 3D mannequin mesh. Then, shape-blending methods can be applied and systematically change the shapes using parameters, the varied requirements in fashion design concerning 3D mannequin suitable for different individual sizes can thus be met [20]-[23]. Finally, through mesh algorithm, surface with G2 continuity can be generated from the original mesh control [24]. This is different from the previous application that used parameters for 3D mannequin reconstruction. Based on shape features, the scanned data are divided into appropriate blocks and re-simplifying the entire scanned data using slicing methods. When parametric surfaces are needed for the shape reconstruction of already partitioned blocks [25], a relatively common method [26], interpolation is used to obtain the minimum energy. Thus, the continuity of surface convergence becomes an important challenge owing to the reason that the principle of subdivision is based on the relationship between meshes. Therefore, the production of parametric surface can be divided into a high quality surface with G2 continuity. This is the material that can be used in computer-aided fashion design and production [27].

Overall, if one can investigate related research methodology, and propose appropriate algorithm, the study will be more complete. Thus, a more complete and systematic solution can be proposed to the study of applying Kinect on the development of a customized 3D mannequin system.

III. Methodology

A. Mannequin and Shape Morphing

In order to systematically process the size scaling of 3D mannequin with ergonomic parameters, several dotted curves are adapted to the form reconstruction as the auxiliary curves for data partitioning. This results in the primary form model being partitioned by feature curves and then transforms the 3D mannequin form composed of a brick-piling data structure. Furthermore, the meshes for shape morphing are generated on the surface of every brick, as shown in Fig. 5. This makes the management and application of the 3D mannequin data systematic because the sections of specific forms are represented by every brick.

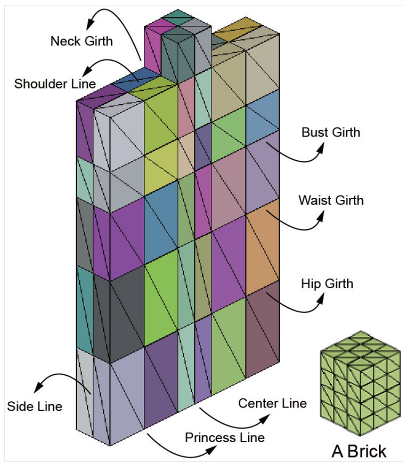


Fig. 5 The 3D mannequin model composed of a brick-pilling data

Through this module, the relation among the 3D mannequin data is built by the relative positions of the bricks while the attribute of layers is contained. When conducting the scaling process of 3D mannequin, the sets of bricks ready to be calculated are derived from the feature measurements of the related data (Fig. 6 (a)). Several ergonomic parameters for shape morphing are defined through the 3D mannequin constructed in this study (Fig. 6 (b)), where the process not only represents the shoulder width W1, waist width W2, and hip width W3, but also the difference, H1 – H5, of heights and the range of girths for each feature profile. Shape morphing of the 3D mannequin includes two stages: scaling of the feature profile and the shape morphing of the related brick data. Scaling of the feature profile includes the adjustment of width and depth; when conducting the width scaling of the feature profile, the point O is the center of the profile, which is applied to the scaling process in the X-axis direction (Fig. 6 (c)). Hence, when conducting the depth scaling of the feature profile, the point O is the center of the profile which is applied to the scaling process in the Z-axis direction (Fig. 6 (d)). Through this method, and after the width of the profile is determined, the girth of the profile is adjusted by the process for the scaling of depth D, especially for the three girths of a human body. When the scaling process of each profile is complemented, the scaling ratio could be applied to the calculation for shape morphing of related bricks, where the difference of the measured heights is the height of each brick. Then, the extension of the brick is conducted in the Y-axis direction based on the center O (Fig. 6 (e)).

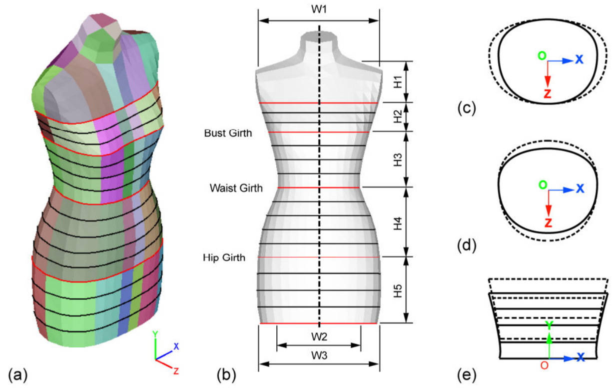


Fig. 6 Scaling of feature profiles. (a) Continuous profiles among the feature curves on the 3D mannequin; (b) definition of ergonomic parameters; (c) scaling of the profile in the X-axis direction; (d) scaling of the profile in the Z-axis direction; and, (e) scaling of continuous profiles in the Y-axis direction

To conduct the process of the shape morphing of a 3D mannequin based on the scaling of feature profiles on the bricks, a weighted blending method is adopted in the study. Shape morphing is the process of continued transformation between two shapes or forms that also includes the conversion of shape features. In order to contain the process continuity, the weighted arithmetic mean method in (1) is applied to calculate the degree of scaling in every axial direction and then generate the output of shape morphing with the specific form features remaining.

$$S_i = W_a \times S_a + W_b \times S_b$$
$$w_a = i/n$$
$$w_b = 1 - w_a \qquad (1)$$

where *n* is the step number for the degree of the shape morphing process, S_a and S_a are the dimensions of form *a* and form *b* respectively, W_a and W_b are the weight of form *a* and form *b* respectively, and S_i is the dimensions of the i-th form of shape morphing.

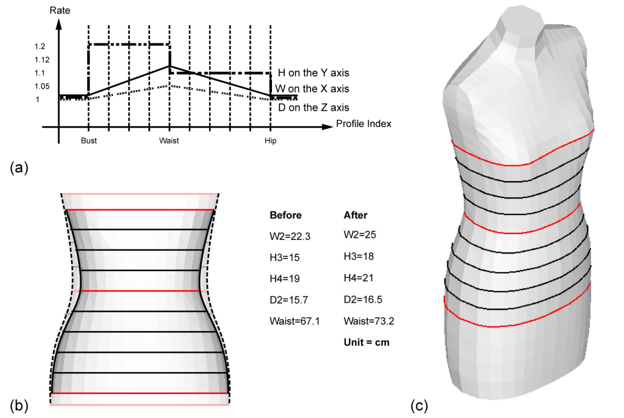


Fig. 7 Application of weighted blending to shape morphing of the waist of a 3D mannequin. (a) Scaling ratio of each axial direction on the profiles; (b) parameters and the appearance of the mannequin before and after the shape morph; and, (c) generation of a new 3D mannequin model after shape blending

When the weighted blending is applied to the waist shape morphing of the 3D mannequin based on the brick-piling data structure, a result as in Fig. 3 is obtained. While adjusting the scaling ratio of the waist profile, the scaling ratios of other profiles on the related bricks are calculated by the weighted blending method (Fig. 7 (a)). This leads to a new waist form being generated according to these scaling ratios (Fig. 7 (b)). After the shape morphing of the partial forms is complete, a new 3D mannequin is built again (Fig. 7 (c)). Through this module, the shape morphing of a 3D mannequin is concurrently generated while simultaneously retaining the scaling of feature profiles with the primarily geometric features.

B. ICP Algorithm

ICP algorithm is widely used among 3D model overlay, it is employed to find out the relationship between two clouds of points then interactive method is used to minimize the distance between the two clouds of points and gradually minimize the error metric. In every interactive method, the point in the source point cloud finds the closest point as the reference point cloud. Then, estimate the smallest error metric in the combination of rotation and translation in order to find the smallest mean squared error cost function. After that, the source points are transformed by using the obtained transformation. Finally, the method is done repeatedly to generate an optimal result. The steps for ICP algorithm is shown as followed.

Step 1: Data Shape Setting and Model Shape Information

The first step of ICP is to set model shape and data shape. The fixed model is called model shape (M), and data shape (D) refers to the one that undergoes registration process. Types for data model can be composed of points, lines, triangles, curves, and curved surfaces. Data shape needs to be composed of points; however as for model shape, there is no limitation, it can be presented into any geometric forms.

Step 2: Stop Condition Setting

The second step for ICP algorithm is to set the convergence criterion. If the error in iteration is bigger than the allowed value, then correction in ICP algorithm should be repeated. On the other hand, if the error decreased and is smaller than the allowed value, the iteration process should be stopped. Theoretically, if the criteria for stopping the condition setting are small, a better correction result will be obtained. However, it could also make the whole ICP correction process continues endlessly. Therefore, setting for convergence criterion is suggested to base on empirical rules to select an acceptable value.

Step 3: Matching Point

The third step is to look for the correspondences between data shape and model shape, which is the reference point with minimized distance. That is, taking data shape (D), P_i , as the reference point and search for the closest point in model shape (M), X_i . Then a correspondent pair, $P_i \leftrightarrow X_i$, occurs. The position for P_i and X_i has to be recorded.

Step 4: Computation in Geometric Conversion

After finding the point to point correspondent in step 3, data shape (D) can then be computed in geometric conversion.

Step 5: Coordinates Updating

In the previous steps, conversion matrix is computed; therefore, the data can be used to update the coordinates in the original data shape (D). After updating, the result can be used in the next registration to look for the correspondent of data shape (D). One thing to be noticed is that, in step 3, the correspondents in data shape is the updating coordinates in the precious registration. As for step 4, the coordinates used in geometric conversion is the original data shape position, which is different from step 3. Furthermore, original data shape is used owing to the reason that geometric conversion is applied to correct model shape by using original data shape. On the other hand, updated data after geometric conversion is used in the next registration for the search of closest correspondents. Hence, ICP algorithm uses two different ways to search for the closest distance in the correspondence. Geometric conversion is computed and two ways interact with each other, and finally minimize the difference between two clouds of points.

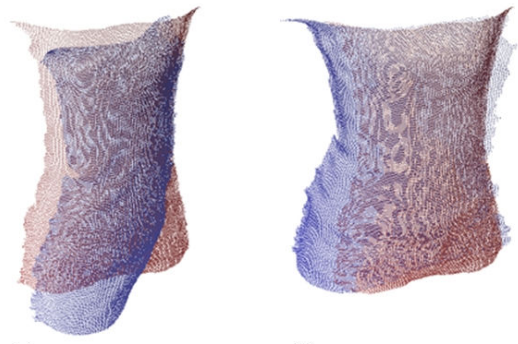
Step 6: Computation in Mean Square Error

After updating the coordinates in data shape, MSE (Mean Square Error) for the two models can therefore be computed.

Step 7: Decision Making

Calculate the difference of the MSE between two difference iterations, and check whether the error is smaller than the given allowed value. The iteration process will be stopped until the given criteria is satisfied.

After implementing the ICP algorithm, the error for the two scanned surfaces with large error as shown in Fig. 8 (a) can be minimized, and the two surfaces can be superimposed together after the convergence results are obtained, as shown in Fig. 8 (b).



(a) (b)

Fig. 8 Applying ICP algorithm to superimpose the scanned data (a) Before iteration (b) After iteration

IV. Case Study

A. Applying Kinect Sensing Devices for 3D Scan

When the Kinect sensing devie is applied for 3D scanning, the API offered by OpenNI is used to obtain the depth information. The inofrmation is then converted to calculate the 3D position of each Pixel to get the scanned surface. In order to get a more smooth scanned result, point to point smoothing process should be implemented. This is the pre-treatment work for Kinect data scanning. To get different surfaces of a complete object, steps mentioned above should be repeated. Then, based on the shapes of the scanned surfaces, ICP algorithms is implemented, to get the superimposed model with a minmum error gotten descried previously. After the 3D shape mannequin is reconstructed, three girths of human body can be obtained to get the human factor measurements for the related mqnnequin, which can also be used to get the grid mesh of the 3D mannequin.

In the present study, 8 different scanned surface models were gotten by taking a picture from every 45 degrees clockwisely, or counterclockwisly (Fig. 9). When the 8 pictures are obtained, the first step of human body scanning is completed. Furthermore, when scanning, the human body is in motion. A distinctive scanning result is difficult to be obtained. Hence, motion in human body should be pre-defined as shown in Fig. 10 (a). Then, the main body, head and limbs could be identified through feature recognition Fig. 10 (b). Among all, main body is the only part that can undergo 3D data iteration by using ICP algorithm, then followed by related measurements to get human dimensions from the main body. This can then be applied to the 3D mannequin transformation to get the required customarized 3D shape mannequin.

B. Shape Morphing of a 3D Mannequin

The participant can wear casual clothes when applying Kinect sensing devices in human body measurement scanning (Fig. 11 (a)) and through ICP algorithm iterations to get the 3D scanned configuration (Fig. 11 (b)). The ergonomic parameters defined by the present study can be searched by using feature recognition. After imputing the parameters into the applied system to the relative bricks, a customarized 3D mannequin can therefore be produced (Fig. 11 (c)).

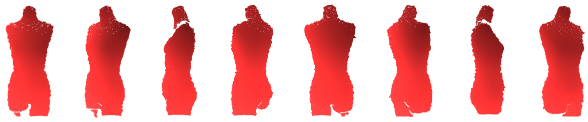


Fig. 9 Kinect sensing devices in 8 different directions for the scanning

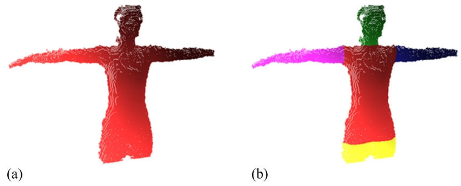


Fig. 10 Human body scanning. (a) Defined scanning gesture; and, (b) feature recognition search in human body, head and limbs

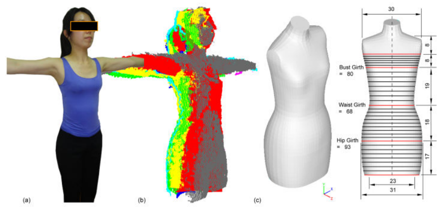


Fig. 11 Shape morphing of a 3D mannequin. (a) Ergonomic measurements of the subject; (b) 3D scanning for a human body; and, (c) the 3D mannequin constructed based on the erogonomic parameters (unit:cm)

V. Results and Discussion

A 3D mannequin construction method with the depth camera of Kinect to measure different measurements of the subject is proposed in this study. In this method, a customized 3D mannequin can be obtained by inputting the constructed model into the system to change the control point for shape morphing. During the process, the most important question is how to get a precise 3D point data by applying Kinect scanning which directly infleunce the result of ICP algoritm. Moreover, a more efficient algorithm can be obtained by implementing image processing method to the ICP algorithm to improve data matching. This is the direction of future developments for the various applications in Kinect scanning on 3D mannequin system to benefit the construction and development of the whole system.

Acknowledgment

We really appreciate that the Ministry Science and Technology of Taiwan for supporting this project under contract no. NSC102-2221-E-006-188-MY3.

References

[1] C. K. Au, and Y. S. Ma, "Garment pattern definition, development and application with associative feature approach," Computers in Industry, vol.61, pp.524-531, 2010.
[2] C. K. Au, and M. M. F. Yuen, "A semantic feature language for sculptured object modeling," Computer-Aided Design, vol.32, pp. 63-74,2000.
[3] S. M. Kim, and T. J. Kang, "Garment pattern generation from body scan data," Computer-Aided Design, vol.35, pp. 611-618, 2002.
[4] C. K. Au, and M. M. F. Yuen, "Feature-based reverse engineering of mannequin for garment design," Computer-Aided Design, vol.31, pp. 751-759,1999.
[5] J. McCartney, B. K. Hinds, and K. W. Chong, "Pattern flattening for orthotropic materials," Computer-Aided Design, vol.37, pp. 631-644, 2005.
[6] C. C. L. Wang, T. K. K. Chang, and M.M.F. Yuen, "From laser-scanned data to feature human model: a system based on fuzzy logic concept," Computer-Aided Design, vol.35, pp. 241-253, 2003.
[7] C. C. L. Wang, Y. Wang, T. K. K. Chang, and M. M. F. Yuen, "Virtual human modeling from photographs for garment industry," Computer-Aided Design, vol.35, pp. 577-589, 2003.
[8] C. C. L. Wang, Y. Wang, and M. M. F. Yuen, "Design automation for customized apparel products," Computer-Aided Design, vol.37, pp. 83-98, 2005.
[9] C. C. L. Wang, Y. Wang, and M. M. F. Yuen, "Feature based 3D garment design through 2D sketches," Computer-Aided Design, vol.35, pp. 659-672, 2002.
[10] J. Wang, G. Lu, W. Li, L. Chen, and Y. Sakaguti, "Interactive 3D garment design with constrained contour curves and style curves," Computer-Aided Design, vol.41, pp. 614-625, 2009.
[11] D. L Son et al., Multi-finger interactions with papers on augmented tabletops. In Proc. 3rd International Conference on Tangible and Embedded Interaction,2009 ,pp. 267-274.
[12] J. Taylor et al, "The vitruvian manifold: inferring dense correspondences for one-shot human pose estimation," Microsoft Research, 2012.
[13] S. Izadi et al., Kinect Fusion: Real-time 3D reconstruction and interaction using a moving depth camera. in Proc. 24th Annu. ACM symposium on User interface software and technology,2011,pp. 559-568.
[14] R. A. Newcombe et al., Kinect Fusion: Real-time dense surface mapping and tracking. In Proc. Mixed and Augmented Reality (ISMAR), 2011 10th IEEE International Symposium on, 2011, pp.127-136.
[15] W. D. Ueng, Lai JY and Doong JL. "Sweep-surface reconstruction from three-dimensional measured data," Computer-Aided Design, vol.30, pp. 791-805, 1998.
[16] P. J. Besl, and N. D. Mckay, "A method for registration of 3D shapes," IEEE Trans. Pattern Anal. Mach. Intell., vol.14, pp. 239-256, 1992.
[17] S. Rusinkiewicz, and M. Levoy, Efficient variants of the ICP algorithm. In Proc. 3D Digital Imaging and Modeling, Int. Conf. on, 2001.
[18] S. Rusinkiewicz, O. Hall-Holt, and M. Levoy, "Real-time 3D model acquisition," ACM Trans. Graph., 2002.
[19] B. Huhle, T. Schairer, P. Jenke, and W. StraBer, "Fusion of range and color images for denoising and resolution enhancement with a non-local filter," Computer Vision and Image Understanding, vol.114, pp. 1336-1345, 2010.
[20] S. W. Hsiao, and J. C. Chuang, "A Reverse Engineering Based Approach for Product Form Design," Design Studies, vol.24, pp. 155-171, 2003.
[21] K. C. Hui, and Y. Li, "A feature-based shape blending technique for Industrial design," Computer-Aided Design, vol.10, pp. 823-834, 1998.
[22] H. Q. Huang et al. "Block pattern generateon: From parameterzing human bodies to fit feature-aligned and flattenable 3D garments," Computers in Industry, vol.63, pp. 680-691, 2012.
[23] J. Li, and G. Lu, "Customizing 3D garments based on volume deformation," Computers in Industry, vol.62, pp. 693-707, 2011.
[24] W. Ma, "Subdivision surface for CAD – an overview," Computer-Aided Design, vol.37, pp. 693-709, 2005.
[25] Y. Ke, S. Fan, W. Zhu, A. Li, F. Liu, and X. Shi, "Feature-based reverse modeling strategies," Computer-Aided Design, vol.38, pp. 485-506, 2006.
[26] Y. Ke, W. Zhu, F. Liu, X. Shi, "Constrained fitting for 2D profile-based reverse modeling," Computer-Aided Design, vol.38, pp. 101-114, 2006.
[27] J. Li, and G. Lu, "Customizing 3D garments based on volume deformation," Computers in Industry, vol. 62, pp. 693-707, 2011.