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Applying Multiple Kinect on the Development of a Rapid 3D Mannequin Scan Platform

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***Abstract*—**In the field of reverse engineering and creative industries, applying 3D scanning process to obtain geometric forms of the objects is a mature and common technique. For instance, organic objects such as faces and nonorganic objects such as products could be scanned to acquire the geometric information for further application. However, although the data resolution of 3D scanning device is increasing and there are more and more abundant complementary applications, the penetration rate of 3D scanning for the public is still limited by the relative high price of the devices. On the other hand, Kinect, released by Microsoft, is known for its powerful functions, considerably low price, and complete technology and database support. Therefore, related studies can be done with the applying of Kinect under acceptable cost and data precision. Due to the fact that Kinect utilizes optical mechanism to extracting depth information, limitations are found due to the reason of the straight path of the light. Thus, various angles are required sequentially to obtain the complete 3D information of the object when applying a single Kinect for 3D scanning. The integration process which combines the 3D data from different angles by certain algorithms is also required. This sequential scanning process costs much time and the complex integration process often encounter some technical problems. Therefore, this paper aimed to apply multiple Kinects simultaneously on the field of developing a rapid 3D mannequin scan platform and proposed suggestions on the number and angles of Kinects. In the content, a method of establishing the coordination based on the relation between mannequin and the specifications of Kinect is proposed, and a suggestion of angles and number of Kinects is also described. An experiment of applying multiple Kinect on the scanning of 3D mannequin is constructed by Microsoft API, and the results show that the time required for scanning and technical threshold can be reduced in the industries of fashion and garment design.

***Keywords*—**3D scan, depth sensor, fashion and garment design, mannequin, multiple kinect sensor.

I. Introduction

NOWADAYS, applying 3D scanning to obtain geometric forms of the object is a mature technique. It is commonly used in reversed engineering and creative industries. For instance, the technique has been applied to scan nonorganic object such as products, and organic object such as faces. However, although the precision of 3D scanning data is increasing, and the complementary applications are more and more abundant, also the price for 3D scanning is still considerably high. Therefore, the application of 3D scanning will be less available for the public.

Microsoft Corporation announced Kinect360 body motion sensor in 2010. At first, the purpose is to replace gaming controls and allow users to use body motions to select media content. This is to substitute WIMP (Windows, Icons, Mouse, Pointer) through a natural user interface. It is another major breakthrough in human computer interaction field after touch-screen interface was invented. Kinect360 features an RGB camera, depth sensor which can sense distance, and skeletal tracking. With its powerful functions, considerably low price, and complete technology and database support, related studies can be done with the applying of Kinect under acceptable cost and precision.

In 2013, after the success of Kinect360, Microsoft launched the second generation of Kinect-Kinect V2, which was released at the same time as Xbox One. To distinguish between the two generations, this study referred Kinect V2 as Kinect, and the first generation is called Kinect360. Different from the first generation, the component of its core 3D sensing element changed from structure light to time of flight. This increases the precision of obtaining depth information and thus extend the field of application. Fig. 1 shows the first generation Kinect-Kinect360 (a), second generation Kinect-Kinect V2(b), and the depth information obtained from Kinect V2(c).

(a) (b) (c)

Fig. 1 (a) First generation Kinect-Kinect360, (b) second generation Kinect-Kinect V2, (c) depth information obtained by Kinect V2

Due to the fact that Kinect uses optical method for extracting 3D information, it would encounter difficulties owing to the reason of the straight path of the light. Kinect will not be able to record depth information if there is an obstacle on the straight line between any point *(i)* on the scan object and Kinect sensor lens, or when the angle θ_{NV} of the point i between the normal vector $\vec{N}_i$ and the vector $\vec{V}_i$ of the point to the Kinect lens are bigger than 90 degrees (shown as Fig. 2). Therefore, similar to other types of 3D scanners, when applying single Kinect for 3D scanning, if a point (*i*) on the object cannot be detected by the direction of the Kinect, multiple angles are required sequentially for extracting the complete 3D information of the object. Thus, 3D data from multiple angles will undergo integration process to become complete object by certain algorithms. This will cost much time during the scanning process and encounter technical problems during the integration process. However, due to the higher cost of 3D

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scanning device in the past, single device sensing was a compromised solution between costs and efficiency. On the other hand, due to the reason that Kinect has a lower price under acceptable resolution, it can fulfill the requirement of matrix-scanning system to obtain 3D data from different aspects at the same time through multiple Kinects from different angles. This leads to a faster 3D scanning process. This paper aimed to apply multiple Kinects on the development of a rapid 3D mannequin scan platform and proposed suggestions on the number and angles of Kinect.

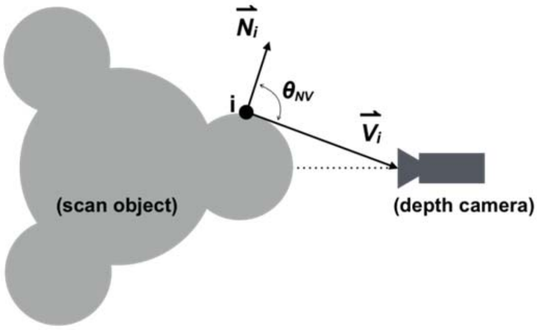

Fig. 2 Illustration of θ_{NV} of point *i* on the scan object

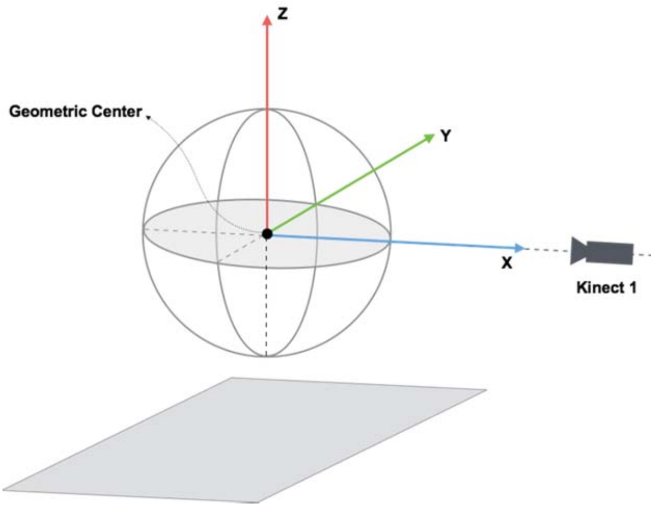

Fig. 3 Establish coordination of scan object

II. Literature Review

Since the launch of Kinect, it has been extensively applied in numerous fields. For instance, related studies have been found by using skeletal tracking for human computer interaction [1], navigation of quadrotor control [2], feedback of flying disc [3], and postures at work [4]. Moreover, there are studies that focus on conversation between hand gestures and computers, for instance in medical field [5], and entertainment area [6]. In terms of gait analysis, there is study attempted to replace the previous sensor by Kinect [7]. On the other hand, in depth detection, obstacle detection [8] is also found, and so do studies about estimation on animals' weight and health status [9], [10]. Studies about the difference between Kinect and Kinect360 were also found [11]. As for the application for multiple Kinect, related studies used multiples Kinect to form a metrical scanning system, interactive 180-degree projection in public relations were found [12]. However, the scanning inside-out process is different from the present study, which scan from the outside towards the inside.

In the field of mannequins and fashion or garment design, utilizing reverse engineering on mannequin scanning is widely adopted [13]-[15]. There are studies applying 3D laser to extract curves from human models [16], and studies applying the photographs to rebuild human models [17]. Moreover, there are studies in parameterization and parametric design of mannequins [18], the use of 2D sketches to build design system [19], automation design for apparel products [20], and interactive design [21]. However, there is few studies using multiple Kinects for scanning on 3D mannequins.

In terms of 3D data extraction and representation, it is a mature technique to present the data in cross-sectional curve [22]. Data are presented in straight line or curve [23] or in a B-spline curve fitting [24], which are all the methods of processing original 3D scanning data [25]. After obtaining sectional area, characteristic curve can be built [26] along with feature-based shape blending [27] and steps [28]. After the 3D data have been processed [29], original spatial point can be parameterized, and continue the next step for study and application.

III. Methodology

Applying multiple Kinects on 3D object scanning can not only increase scanning efficiency but also reduce the difficulty in processing scanned results of data clouds. This study aimed to construct multiple Kinect for a 3D scan platform. Firstly, global coordinate systems of the Kinects with respect to scan object can be established. Secondly, based on the geometrical shape and characteristic of the scan object to determine the number and location of Kinect sensors. After the object has been scanned, coordination rotation is applied to the integration of raw data from Kinects to obtain complete 3D scanned results. Steps are described in the follows.

A. Coordination Setup

Owing to the reason that there is a fixed range in Kinect angle and distance, the distance between Kinect and the scan object should be taken into consideration. Assume the geometric center of the object as the origin and establish a Cartesian coordinate system, the X-Y surface was parallel to ground horizontal surface, and the Z axis is orthogonal to horizontal surface, the first Kinect (Kinect1) was set along with the X axis (shown as Fig. 3). The distance, x_1, between the scan object and Kinect sensor (Kinect 1) should follow (1), (2):

$$d_{min} < x_1 - \frac{d_{x-max}}{2} < d_{max} \tag{1}$$

$$d_{min} \tan\frac{\theta}{2} < \frac{d_{y-max}}{2} < d_{max} \tan\frac{\theta}{2} \tag{2}$$

Among all, d_{min} is the minimum scanning distance, and d_{max} is the maximal scanning distance of Kinect sensor. In addition, θ is the maximal horizontal scan angle, and d_{x-max} is the maximal width of the scan object on X-axis, d_{y-max} is the maximal width of the scan object on Y-axis, as shown in Fig. 4.

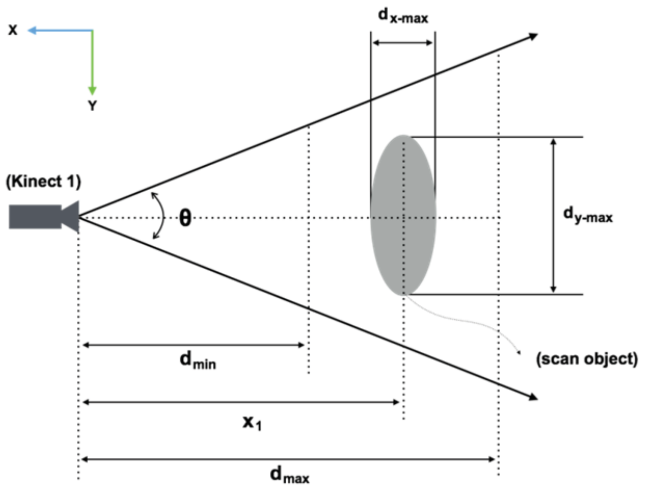

Fig. 4 Relationship between distance of Kinect1 along X-axis and the width of object on Y-axis

Similarly, the following conditions (3) should be followed on Z-axis.

$$d_{min} \tan\frac{\phi}{2} < \frac{d_{z-max}}{2} < d_{max} \tan\frac{\phi}{2} \quad (3)$$

Among all, ϕ is the maximal vertical scan angle, and that d_{z-max} is the maximal width for the scan object on Z-axis (shown as Fig. 5).

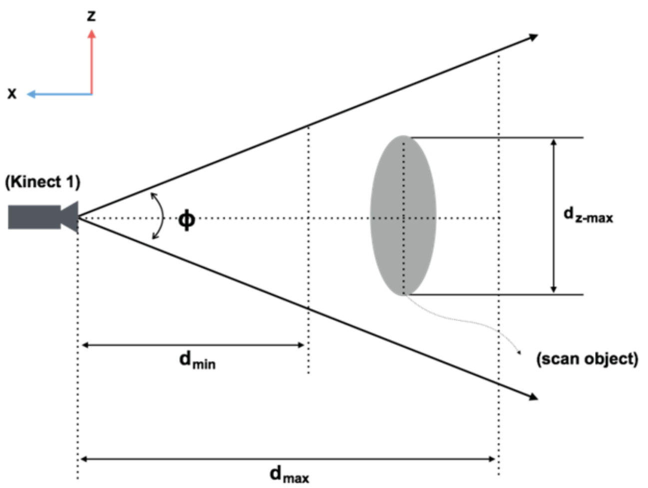

Fig. 5 Relationship between distance of Kinect1 along X-axis and the width of object on Z-axis

B. Setup Sensors

After obtaining location for the first Kinect-Kinect1 (x_1, 0,0), numbers and locations for the Kinect can be determined based on the geometrical characteristics of the scan object (shown as Fig. 6). Take example from the cross sectional area of the object on the X-Y surface. Assume the maximal range of the object that can be detected by Kinect1 is between two end points P1, and P2. If there are no obstacles between certain point i on the object $\vec{V}_i$ towards Kinect 1, and the angle between $\vec{V}_i$ and the normal vector of point i, $\vec{N}_i$, is smaller than 90 degrees, this area can be recorded by Kinect1 completely. If not, extra sensor should be taken into consideration. Next, establish a virtual coordinates (X',Y',Z') and rotate a certain degree, α, along Z-axis until P2 falls on the the X'-axis of new coordinate,. Therefore, Kinect2 can be set on the Y'-axis of the new coordinate (shown as Fig. 7). The distance should also match the conditions mentioned in the previous paragraph (1)(2)(3). Moreover, P3 was set on X'-axis as the other end point of maximal distance which can be scanned by Kinect 2, and previous steps were repeated and the virtual coordinates were rotated to obtain Kinect 3, Kinect 4… until Pn has rotated a circle and fall between P1 and P2. Then, n is the number of Kinects that is needed.

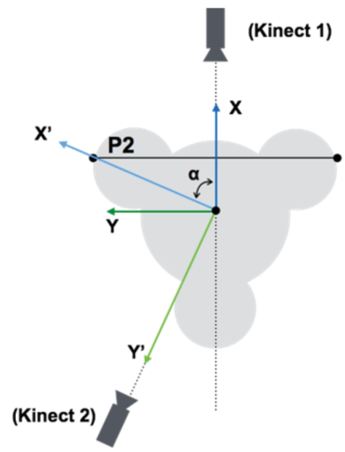

Fig. 6 Rotation angle of the virtual coordination

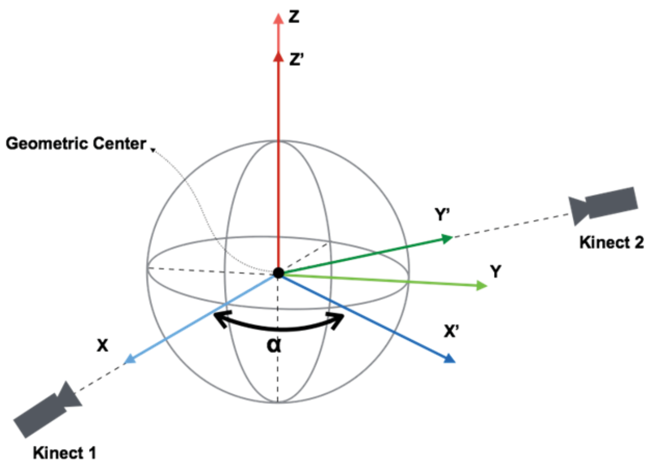

Fig. 7 Determine virtual coordinates for Kinect2

C. Coordination Rotation

After the number and location for Kinect is confirmed, and the data are imported from Kinect1, Kinect2… Then, the *i-th* Kinect can be transferred with respect to the coordination of the scan object according to the known formula (shown as Fig. 8).

$$\begin{bmatrix} x_{obj-ki} \\ y_{obj-ki} \end{bmatrix} = \begin{bmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} x_{ki} \\ y_{ki} \end{bmatrix} \quad (4)$$

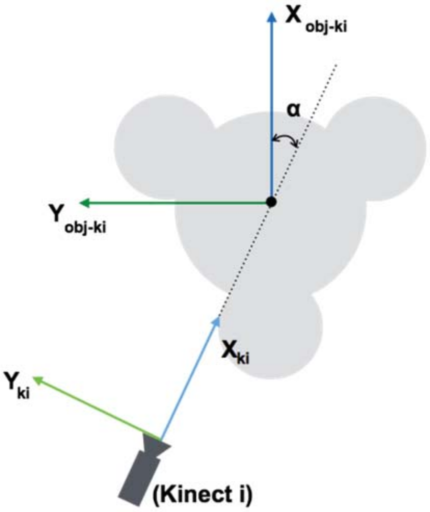

Fig. 8 Transferring the data from Kinect i with respect to scan object

IV. Case Study

The study applied multiple Kinects on the scanning of mannequin. Mannequin is used widely on cloth or garment design, and extensively applications could be found in the fashion design industry. In the present stage, the method of fashion design can be divided into two main categories- one is 2D pattern cutting that cut garment on the templates, and later on to form a complete cloth by sewing, the other is 3D design on mannequin, and then applying surface flattening technique to export the shape of the fabric. Due to the popularity of computer-aided design, the usage of digital 3D mannequin is becoming more and more common. Therefore, by utilizing reverse engineering methodology to scan mannequin and extract the special curve, the efficiency of fashion design can be increased and also the need of human factors and ergonomics can be fulfilled.

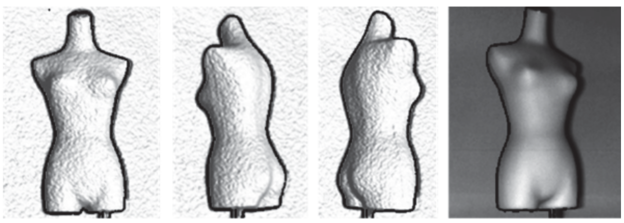

Fig. 9 Applying multiple Kinects to extract and integrate mannequin data from different angles

This study applied multiple Kinects to scan mannequins. Depth information data were obtained through the use of API provided by Microsoft. Moreover, the method described above was obtained to determine the location of Kinects and the integration of the receiving data. Fig. 9 presents an example of using multiple Kinect to extract and integrate mannequin data from different angles. Fig. 10 demonstrates an example of extracting and integrating soft fabric. This method provides a simple and rapid way of conducting 3D mannequin scanning for the fashion design and garment design industries.

Fig. 10 Example of extracting and integrating soft fabric

V. Result and Discussion

The present study focused on applying multiple Kinects to the scanning of a single mannequin simultaneously and proposed the establishment of the coordinate system and methods to determine numbers and angles of Kinects, and finally the integration of the scanned results. Compared to the previous method of rotating the mannequin to extract data from various angles through one single Kinect, multiple Kinect scanning in the experiment shows that the time required and technical threshold can be reduced in 3D mannequin system and fashion design industries. However, a more intuitive and interactive multiple Kinect scanning environment can be built if a better algorithm for processing 3D data registration can be applied.

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