Product 3D virtual display scene modelling based on augmented reality technology

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Abstract: In order to overcome the problems of low precision and long time in traditional methods, a 3D virtual display scene modelling method based on augmented reality technology is proposed. The 3D virtual display scene image of the product is obtained by camera, and the 3D virtual display scene coordinate is obtained by using the 3D registration technology in augmented reality. The real product scene image and virtual position are synthesised in virtual reality according to the acquired 3D space coordinates, and the geometric distortion phenomenon generated in the synthesis process is corrected. After the correction, the 3D virtual display scene coordinates are obtained, the product scene image is binary processing, the product image contour is extracted, and the 3D virtual display scene of the product is generated. The simulation results show that the modelling accuracy of this method is kept at 95%, and the modelling time is only 4 s.

Keywords: augmented reality technology; 3D virtual; display scene; 3D registration technology; anti-perspective transformation method.

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1 Introduction

With the continuous development of science and technology, virtual reality technology has gradually become an indispensable means in people's life and occupies a certain position in the field of industrial design. Industrial products make prototypes by manufacturing product models, and then realise subsequent development through prototypes. The adoption of virtual reality technology is to integrate these series of steps, so that the sales mode is no longer constrained by time and space. Therefore, virtual reality technology further promotes the further development of e-commerce (Kou et al., 2018; Kim et al., 2020; Xiong et al., 2019). In the past, the traditional means of product sales is to use product pictures and text for publicity, or put the product in kind on the display shelf, so that consumers can directly hit the product and have a certain understanding of the product. However, it not only reduces the scope of consumer groups, but also improves the sales cost of the product and reduces the sales profit. Product 3D virtual display scene is the use of virtual reality technology for all-round 3D virtual display of products, so that consumers can more intuitively view the details of the product, this way of display can fully stimulate the consumer demand. In the product 3D virtual display scene, consumers can also customise and make personalised products by yourself, which can not only reduce the design cost, but also effectively control the product inventory and accurately predict the product production. Therefore, it is necessary to carry out product 3D virtual display scene modelling, so as to optimise the product display details and enhance consumers' interest in the product to improve product sales, it is of great significance to build product 3D virtual display scene model (Zeng et al., 2020; Wu, 2019).

Lin (2019) uses 3DMAX to build a 3D virtual stage scene, which is composed of molecular models of multiple stages. Therefore, by editing and adding 3D stage effects, sub models are built. According to each molecular model, VRP editor is used to layout and plan the stage. Combined with 3DMAX technology and skybox technology, the action and rendering of stage plug-in are completed. In the stage environment, the 3D virtual stage scene is constructed according to the action command. However, this method has the defect of long modelling time in practical application, and the practical application effect is not ideal. Zhou et al. (2019) proposed a method of constructing virtual display scene of 3D garden vegetation landscape based on virtual reality technology. Firstly, parametric generation method was used to obtain plant morphological structure parameters of garden green space. According to plant morphological structure parameters, 3D plant modelling model was constructed, and plant spatial layout method was used to plan plant spatial layout. The virtual display scene of 3D garden vegetation landscape is constructed with virtual reality technology. However, the construction accuracy of this method is low, which leads to the poor construction ability of the scene. Wu et al. (2020) proposed a modelling method of 3D structure virtual display scene of ancient buildings based on MapGIS and SketchUp. Firstly, the 3D structure model of ancient buildings is constructed by using MapGIS, and then the virtual display visualisation scene is established by using SketchUp according to the 3D structure model. The virtual display scene is perfectly combined with the actual scene to complete the construction of 3D structure virtual display scene of ancient buildings, it lays a foundation for the development and management of tourist attractions. However, in the application process, it is found that the performance of this method in modelling accuracy and modelling time is poor, and there is a large gap with the ideal application effect. Zhou et al. (2019) proposed a multi view based modelling method for product 3D virtual display scene. The camera is used to obtain the actual product image. Based on the actual product image, SIFT algorithm is used to extract the product image features to obtain the sparse product image. The sparse product image is converted into the dense product image. According to the dense product image, the actual scene is fused into the virtual field. In the scene, the Poisson equation is used to construct the 3D virtual scene, which realises the construction of the product 3D virtual display scene. However, although this method has achieved relatively ideal results in the construction of 3D virtual display scenes of products, and the construction effect is good, the construction time of 3D virtual display scenes of products is long, leading to low efficiency of scene construction.

Augmented reality technology, also known as AR technology, is a new means of computer image processing. It has developed well in the industrial field, e-commerce field, tourism field and so on. Augmented reality is an object in 3D space using computer means to display, and the generated scenarios to enhance, on the forms of virtual presents for people not exist in the physical image of the world, and the visual effects will be more vivid and perfect, so in order to solve the above problems existing in the method, in this paper, using the augmented reality technology, The modelling of three-dimensional virtual display scene of products is studied, which makes the modelling accuracy of this method high and the modelling time short. The overall design scheme of this method is as follows:

1 The 3D virtual display scene image is obtained by camera, and the 3D virtual position marked in the real space is calculated by using the 3D registration technology in virtual reality, and the 3D virtual display scene coordinate is obtained.

2 The virtual and real-world synthesis technology is used to synthesise the real product scene image and virtual position according to the acquired 3D space coordinates. The geometric distortion phenomenon in the virtual reality synthesis process is corrected by the reverse perspective transformation method. The corrected product scene image is binary processed by selecting the appropriate threshold value, extracting the product image contour and generating production, and the 3D virtual display scene of the product.

3 The modelling accuracy and modelling time of different methods are compared by experiments.

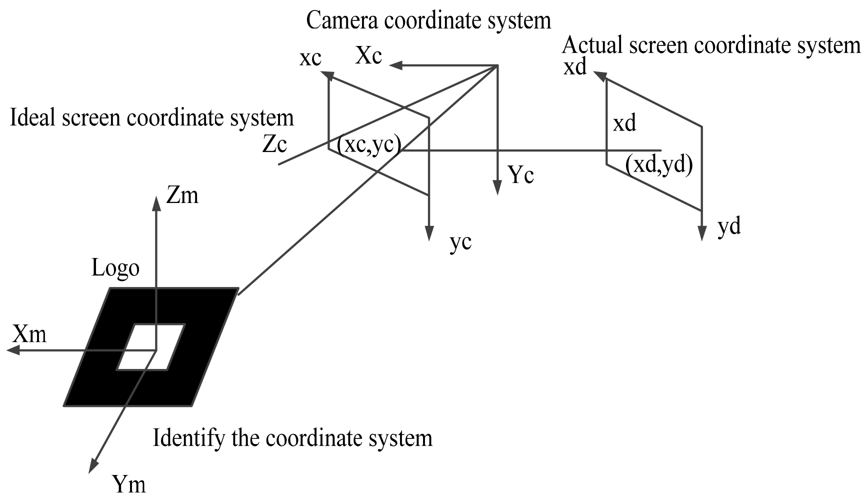
2 3D virtual display scene modelling of products based on augmented reality technology

The camera is used to obtain the 3D virtual display scene image of the product, and the 3D virtual position marked in the real space is calculated by the 3D registration technology in virtual reality to obtain the 3D virtual display scene space coordinates of the product (Zhong et al., 2018; Gorbunov and Nechaev, 2020). Then the virtual reality synthesis technology is used to compare the real product scene image with the virtual position according to the obtained 3D virtual display scene space coordinates of the product Virtual reality synthesis, in order to achieve the accurate and seamless fusion of real environment and virtual objects (Verde et al., 2020). However, in the process of virtual reality synthesis, due to improper camera parameter settings, distortion and other reasons, the product scene image has distortion or deformation. Therefore, this paper uses the reverse perspective transformation method to correct the product image identification, selects the appropriate threshold value to binarise the corrected product scene image, extracts the product image contour, and constructs the product 3D image 3D virtual display scene (Liu and Luo, 2019; Shevchuk et al., 2020).

2.1 Determination of spatial coordinates of product 3D virtual display scene

3D registration technology is the main technical step in product 3D virtual display scene modelling. If the products in the real scene and the products in the virtual environment cannot be perfectly integrated, it will give users a false appearance. Therefore, this paper uses 3D registration technology to determine the accurate 3D coordinates of the product in the 3D virtual display scene space and obtain the contour position (Xu et al., 2018; Wang et al., 2019). The closed black square is used as the frame logo, and the coordinate system based on logo is introduced to complete the 3D registration of product virtual display scene space coordinates. By obtaining the relationship among the identification coordinate system, camera coordinate system and ideal screen coordinate system, the position of the product in the actual screen coordinate system is calculated, and the spatial coordinates of the product 3D virtual display scene are determined (Zhang and Fei, 2019; Xu et al., 2019). The coordinate system based on identification is shown in Figure 1.

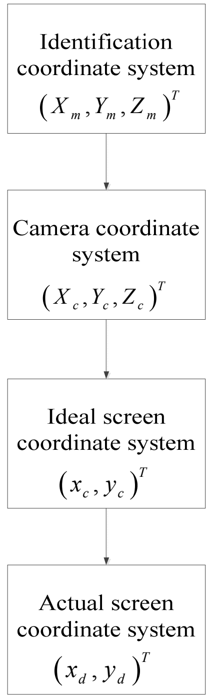
Figure 1 Coordinate system based on identification



Set the mark centre as the origin of the mark coordinate system $(X_m, Y_m, Z_m)^T$, the mark area as the $X_m Y_m$ area, and the vertical axis of the mark coordinate system as Z_m; the optical centre (x_0, y_0) of the camera is the origin of the camera coordinate system $(X_c, Y_c, Z_c)^T$, the $X_c Y_c$ plane is located in the focal plane, and the Z_c axis is The optical axes coincide; the ideal screen coordinate system is $(x_c, y_c)^T$; the actual screen coordinate system is $(x_d, y_d)^T$, and the camera parameter is *S*.

First input the product information in the logo coordinate system into the camera coordinate system, then output the information obtained by the camera into the ideal screen coordinate system, and finally convert the information in the ideal screen coordinate system to the actual screen coordinate system, and the camera will image. The process is shown in Figure 2.

Figure 2 Camera imaging process



To determine the spatial coordinates of the 3D virtual display scene of the product, first obtain the relationship between the logo coordinate system, the camera coordinate system and the ideal screen coordinate system, and then calculate the position of the product in the actual screen coordinate system. Use machine vision to obtain the relationship between the logo coordinate system and the camera coordinate system, and calculate the position of the product in the camera coordinate system. The expression is:

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R_{11} & R_{12} & R_{13} & T_1 \\ R_{21} & R_{22} & R_{23} & T_2 \\ R_{31} & R_{32} & R_{33} & T_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} = T_{cm} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} \tag{1}$$

In the formula, R is a 3*3 orthogonal matrix, T is the three translational components $(T_1, T_2, T_3)^T$ of the origin of the mark coordinate system, and T_{cm} is the transformation matrix between the mark coordinate system and the camera coordinate system (Shi, 2018; Zhang et al., 2018).

According to the relationship between the camera coordinate system and the ideal screen coordinate system, the position of the product in the ideal screen coordinate system is obtained. The expression is:

$$\begin{bmatrix} hx_c \\ hy_c \\ h \end{bmatrix} = \begin{bmatrix} f & s & u0 & 0 \\ 0 & af & v0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = S \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} \tag{2}$$

In the formula, h represents time, S represents camera parameters, f represents tilt coefficient, a represents pixel ratio, and ($u0$, $v0$) represents image pixel centre point.

According to the position of the product in the ideal screen coordinate system, the relationship between the logo coordinate system and the ideal screen coordinate system is:

$$\begin{bmatrix} hx_c \\ hy_c \\ h \end{bmatrix} = ST_{cm} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} \tag{3}$$

According to the above three relations, the position of the product in the actual screen coordinate system is calculated to determine the spatial coordinates of the 3D virtual display scene of the product. The expression is:

$$\begin{cases} x = s\left(x_c - x_0\right), y = s\left(y_c - y_0\right) \\ d^2 = x^2 + y^2 \\ p = \left(1 - fd^2\right) \\ x_d = px + x_0, y_d = py + y_0 \end{cases} \tag{4}$$

2.2 Product 3D image correction based on reverse perspective transformation

When the real product scene image is combined with the virtual position, the image processing error occurs due to the shooting angle and other reasons, and the product scene image is deformed. Therefore, the product image identification needs to be corrected. According to the coordinates of the image area, obtain the corresponding coordinates of the product image identification, and use the inverse perspective transformation method to correct the product image identification. The expression is:

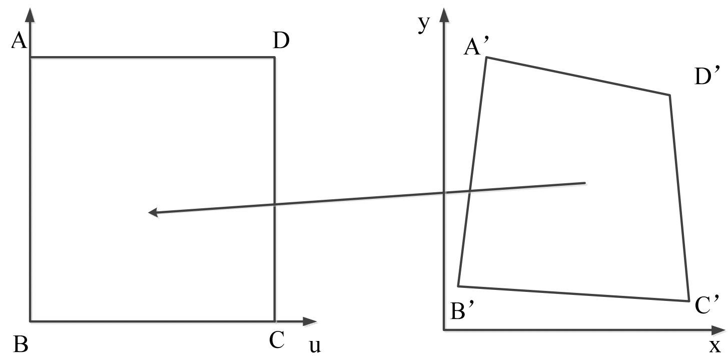
$$\begin{bmatrix} u_i \\ v_i \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} \tag{5}$$

In the formula, $a \sim h$ represents the coordinate factor, (x_i, y_i) represents the original coordinates of the product image identification before correction, and (u_i, v_i, 1) represents the coordinates of the product image identification after correction. The calculation formula of the coordinates is:

$$\begin{cases} u_i = ax_i + by_i + c \\ v_i = dx_i + ey_i + f \\ 1 = gx_i + hy_i + 1 \end{cases} \quad (6)$$

The coordinate diagram of the correction algorithm is shown in Figure 3.

Figure 3 Coordinate diagram of correction algorithm



2.3 Product 3D virtual display scene generation

Select the appropriate threshold to binarise the corrected product scene image, and extract the product image contour twice. The first time the product image contour is extracted, the area of the rectangle enclosing the product scene image contour needs to be obtained, and then according to the obtained contour area, extract the inner contour of the product image with a smaller area; when extracting the product image contour for the second time, draw the area covered by the hand-drawn contour as black based on the inner contour of the product image extracted for the second time and save it as a contour picture, obtain the area covered by the corrected product image logo outline, use Tesseract OCR recognition software to identify the logo in the product image, and get the search key.

According to the Euclidean distance, obtain the nearest hand-drawn contour position of each logo contour, and combine the search keywords and the hand-drawn contour to construct a 3D model. The expression is

$$d(p,q) = \sqrt{(px - qx)^2 + (py - qy)^2} \quad (7)$$

In the formula, p represents the centre of the logo outline, and q represents the centre of the hand-drawn outline.

According to the above formula, the 3D virtual display scene of the product is generated based on the 3D model constructed based on the search keywords and the hand-drawn outline. The expression is:

$$\begin{cases} x = (qx - cx)/(length/2) \\ y = (qy - cy)/(length/2) \end{cases} \quad (8)$$

In the formula, *c*, length represents the maximum contour centre coordinate and side length, and *x*, *y* represents the offset rate of the hand-drawn contour.

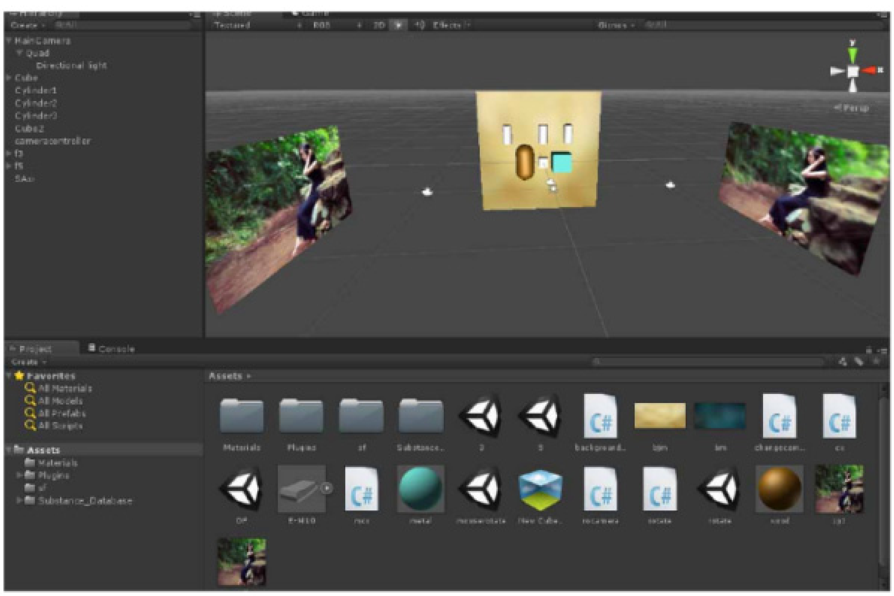
To sum up, this paper mainly obtains the product 3D virtual display scene image through the camera, obtains the product 3D virtual display scene spatial coordinates by using the 3D registration technology in augmented reality, synthesises the real product scene image and virtual position according to the obtained 3D spatial coordinates, and corrects the geometric distortion in the synthesis process. Then, the corrected product scene image is binarised, the product image contour is extracted, the product 3D virtual display scene is generated, and the product 3D virtual display scene modelling is completed. In the next step, we need to use experiments to test the effectiveness of the method, in order to verify the scientificity and reliability of the method.

3 Simulation experiment analysis

3.1 Simulation experiment scheme

In order to verify the performance of the three-dimensional virtual display scene modelling of products based on augmented reality technology constructed in this paper in practical application, experimental tests are needed. In order to improve the reliability and stability of the simulation experiment, the overall experiment scheme is designed in this paper, as shown below.

Figure 4 Scenes built in Unity3d



1 *Experimental environment*: using Visual C++7.0, Vega Prime for simulation experiment analysis. In Unity3d virtual reality simulation environment, build product 3D virtual display scene, as shown in Figure 4.

2 *Experimental data*: according to the above-mentioned 3D virtual display scene of the product, the sampling pixel intensity is 200*300, the resolution is 12dB, the fusion degree of adjacent frames is 0.84, the similarity coefficient is 0.18, and the acquired experimental data is pre-processed to improve the accuracy of the simulation reality.

3 The 3D virtual display scene modelling method based on augmented reality technology proposed in this paper, the 3D virtual stage scene modelling method based on 3DMAX proposed in Lin (2019) and the parameterised virtual vegetation landscape planning and design and virtual display scene modelling method proposed in Zhou et al. (2019) are used as experimental comparison methods.

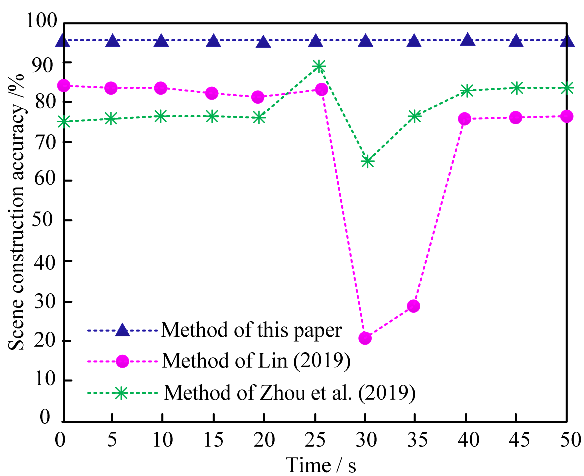
4 *Experimental evaluation index*: take the product 3D virtual display scene construction accuracy and modelling time as the evaluation index, the higher the modelling accuracy is, the finer the product 3D virtual display scene is, the better the application effect is; the shorter the modelling time is, the higher the modelling efficiency is.

3.2 Analysis of experimental results

3.2.1 Comparison of modelling accuracy of different methods

Compare and analyse the construction accuracy of product 3D virtual display scene with different methods, and the comparison results are shown in Figure 5.

Figure 5 Comparison results of modelling accuracy of three methods

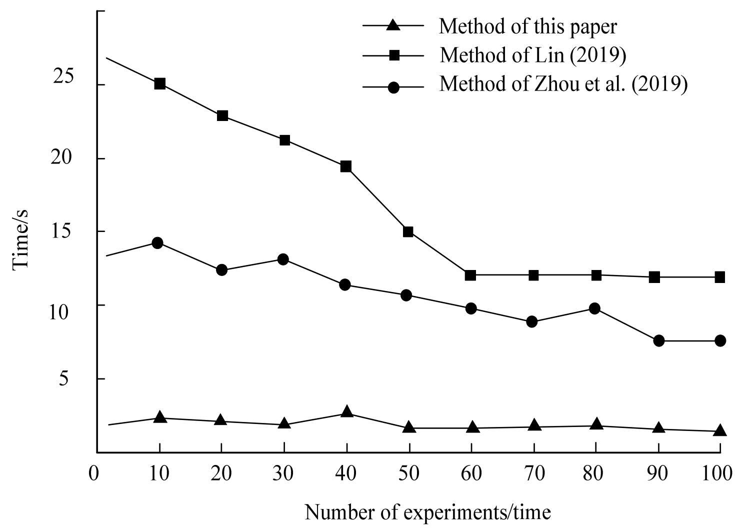


It can be seen from Figure 5 that the modelling accuracy of this method has been maintained at about 95%, while the modelling accuracy of Lin (2019) method and Zhou et al. (2019) method shows a significant downward trend when the experimental time is 25 s, indicating that the modelling accuracy of this method is higher and the scene construction ability is better.

3.2.2 Comparison of modelling time of different methods

In order to further verify the effectiveness of this method, the modelling time of 3D virtual display scene of the product of this method, Lin (2019) method and Zhou et al. (2019) method is analysed. The comparison results are shown in Figure 6.

Figure 6 Comparison results of modelling time of three methods



According to Figure 6, with the increase of the number of experiments, the construction time of 3D virtual display scenes of three methods is declining. The modelling time of reference method is within 28 s, the modelling time of Zhou et al. (2019) method is within 14 s, and the modelling time of this method is within 4 s. It shows that the 3D virtual display field of product based on augmented reality technology constructed in this paper is less than 4 s, the efficiency of scene construction is higher for the experimental comparison method, which shows that the method is more practical.

4 Conclusion

1 With the continuous improvement of science and technology, augmented reality technology has been gradually from immature to mature, and gradually accepted by the public. Because the traditional method of 3D virtual display scene construction of products has low efficiency and unsatisfactory effect, this paper uses augmented reality technology to construct 3D virtual display scene of products.

2 The 3D registration technology is used to determine the spatial coordinates of 3D virtual display scene of products. According to the product coordinates, the product image identification is corrected based on the reverse perspective transformation method. The corrected product image is binary processed by selecting the appropriate threshold value, and the product image contour is extracted, thus the 3D

virtual display scene of the product is generated and the 3D virtual display scene of the product is constructed.

3 The simulation results show that the modelling accuracy of this method is kept at 95% all the time, the modelling time is within 4 s, the modelling accuracy is high and the time is short, which improves the comprehensive performance of 3D virtual display scene modelling.

4 So the method can fully solve the problems existing in the traditional methods, for the optimisation of the product design and has very important significance, can show the product 3D virtual scene details next further optimisation, to improve product 3D virtual display effect, promote the further development of the product design and its related areas.

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