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A MIXED REALITY SYSTEM FOR VIRTUAL GLASSES TRY-ON

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Abstract

In this paper we present an augmented reality system for automatic try-on of 3D virtual eyeglasses. The user can select from various virtual models of eyeglasses for trying-on and the system will automatically fit the selected virtual glasses on the user's face. The user can see his/her face as in a mirror with the 3D virtual glasses fitted on it. We also propose a method for handling the occlusion problem, to display only those parts of the glasses that are not occluded by the face. This system can be used for online shopping, or short listing a large set of available models to a few before physical try-on at a retailer's site.

CR Categories: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; I.4 [Image Processing and Computer Vision]: I.4.9 Applications;

Keywords: Mixed reality, computer vision and virtual try-on system

1. Introduction

Virtual try-on of glasses provides certain advantages over physical try-on in certain cases. At major retailers, there are hundreds of models available to choose, and it is difficult and time consuming to select a model that looks aesthetically good on one's face. The virtual try-on system can be used to narrow down the selection to a few designs and sizes efficiently and interactively, and possibly by recommendations from an AI-based expert system. Another problem encountered while trying-on sunglasses physically is that the view of the face is not clearly visible, as the color of the lens makes the whole view darker. Furthermore, it is difficult for users who suffer from weak eye-sight to test their look with a pair of new spectacles (which have no lenses) physically. They need to take their original glasses off in order to try-on new glasses, and that makes the view less perfectly seen. Another issue is that the customers are not able to compare two or more spectacles at the same time. They have to memorize their previous looks after each try-on. Virtual try-on system can solve all these problems to a large extent. Since the users are not actually wearing the new spectacles, and also they do not need to remove the actual vision-aid glasses, if they are wearing any, they can see a clear view of face with new spectacles. Furthermore, using virtual system, the users can have many snapshots with multiple virtual spectacles at the same time to compare with each other for help in selection of the design.

Fitting of spectacles on face can be divided into two general categories. The first category is to pre-reconstruct a 3D model of a user's head/face using the user's image(s) and then to fit a 3D spectacle model to this pre-reconstructed 3D head/face model. The advantage of this method is its good fitting result. However construction of good quality face model is still a challenging task and generally it requires manual editing to have a realistic model. The second approach is to superimpose virtual glasses model onto a live face image sequence using related augmented reality techniques. The real face image sequence with virtual glasses looks quite realistic, because the face is from the actual camera images. However, the fitting quality would largely depend on the accuracy of tracking and the augmentation algorithms.

Due to the advantages of virtual try-on of glasses, or of virtual-physical combined approach over purely physical try-on, as mentioned earlier, the virtual try-on of glasses has reasonably good commercial potential in the eyewear market. There are few commercial systems already in use. Users can stand in front of a mirror system and select various virtual eyeglasses and the system allows the user to try 3D eyeglasses virtually. However, they have certain limitations that need to be addressed.

Ray-Ban [http://www.ray-ban.com/singapore/science/virtual-mirror] has developed a virtual glasses try-on system that allows the user to try-on 3D glasses virtually. Their software requires a frontal snapshot of the user, on which several feature points need to be marked manually. The manual initialization limits its applications in real market. SyderGlass [http://www.syderis.com-/en/products/virtual-3d-glasses-tester] has also developed a similar virtual glasses try-on system. However, their solution is not able to scale the virtual glasses properly in order to fit it well on the user's face in some situations. Vacchetti et al. [Vaccetti et al. 2004] developed a fast and reliable 3D tracking system, and in their implementation, they showed that virtual glasses can be superimposed onto a user's face image sequence properly and stably. This method also requires manual initialization in order to obtain several pairs of 2D-3D correspondences between the reference image and a corresponding 3D model. Recently, Oscar et al. developed a live video eyeglasses selection system using computer vision tracking technique [Oscar et al. 2010]. However, as mentioned in their paper, the system is unable to meet real-time performance. In [Kim et al. 2005], a 3D head model is constructed using images taken from three cameras, and a pair of 3D virtual glasses is fitted on the reconstructed 3D model. Similar work has been reported in [Pallett et al.2010].

In this paper, we propose and realize a mixed reality system for virtual glasses try-on which enables the user to view different virtual models fitted on his/her face properly in the current pose. Our system does not require any manual initialization and works in real-time. Spectacles are automatically scaled and oriented to the size and orientation of the user's face as far as the user is within the camera's view. For enhanced realism, we also realize a method to solve the occlusion problem.

2. System Setup

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Our system includes one computer and the virtual mirror system hardware. The computer is used for image processing and augmenting the virtual glasses onto the user's face. The virtual mirror system is used for displaying the glasses try-on virtually. It consists of a life-size display, simple optics and a camera that captures the person's image. The display is oriented vertically. A two-way mirror is positioned at 45 degrees in front of the display and a camera is centered and fixed at 90 degrees to the person whose image is being captured. A schematic diagram is shown below in Figure 1. The camera at the user's face level captures user's image which is displayed on the screen behind the half-mirror. It should be noted that due to camera location being at the user face level, the user will have correct eye-contact with his image, and get a better perception of looking at a mirror. This would not be possible if the camera is placed at a different height, such as on the top of the display. By carefully coating the half-mirror, the loss of light reaching to user through camera-display system can be controlled. Further compensation can be achieved by increasing brightness of the display. When the user stands in front of the mirror system, our virtual glasses try-on system enables him to view the virtual glasses fitting on his real face properly, as if he is wearing a real pair of glasses. A snapshot of the system is shown in Figure 2.

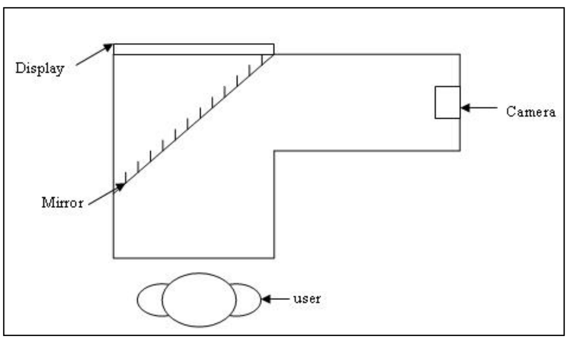

Figure 1. *The two-way mirror system setup.*

Figure 2. *The virtual glasses try-on system.*

3. Mixed Reality Glasses

In our system we use existing real-time vision-based head tracking tools [Morency 2003 and www.seeingmachines.com] to detect the user's head position in 6 DOF. Given a 3D virtual glasses, the purpose is to fit the 3D glasses into a live video accurately in real-time. Some points are marked offline on 3D models of spectacles; however their fitting on the face is done in real-time in each image of the input sequence. The procedure is described below.

3.1 Offline Stage

To fit and augment the virtual glasses onto the user's video, we first specify ten reference points $p_i(i=1,...10)$ on a pair of 3D glasses, as shown in Figure 3, in the offline stage. The reference points p_1, p_2, p_3 and p_4 on the 3D glasses model. i.e., two points on the nose-piece and two points on the left and right arms of a pair of glasses, will be used to augment the glasses on the user's face. The other six points p_5 - p_{10} on the 3D glasses will be used to solve the occlusion problem of the augmented virtual glasses during the online stage, which will be discussed later in this section.

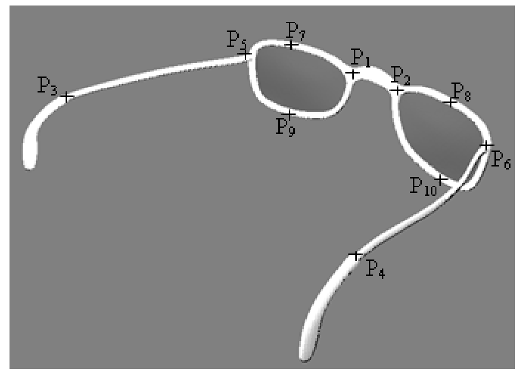

Figure 3. *Our four reference points in the 3D glasses model.*

3.2 Online Stage

We assume that the face coordinate system is centered in the middle of the two eyes, as shown in Figure 4(a) and e_{left} and e_{right}, the centers of both eyes, are obtained using available tools [www.seeingmachines.com], as shown in Figure 4(b). We then detect and track four points $h_i(i=1,...4)$ shown in Figure 4(c) on the user's face in the face coordinate system. These points correspond to $p_i(i=1,...4)$ on the 3D glasses shown in Figure 1, and the two pairs need to match closely for accurate fitting of glasses on the face.

Next, we define Equations (1)-(8) to determine the positions of the four points $\hat{h}_i(i=1,...4)$ in the camera coordinate system which correspond to $h_i(i=1,...4)$ on the user's face in the face coordinate system.

(a) (b) (c)

Figure 4. *a) The face coordinate system given by the tracking tool, b) the positions of the left and the right eyes detected by the tracking tool, c) the corresponding points on the user's face to the 3D glasses model reference points*

$$h_1 = \alpha e_{right} \quad (1)$$

$$h_2 = \alpha e_{left} \quad (2)$$

$$h_3 = \frac{e_{right}}{0.23}\begin{bmatrix}1 & 0 & \beta\end{bmatrix} \quad (3)$$

$$h_4 = \frac{e_{left}}{0.23}\begin{bmatrix}1 & 0 & \beta\end{bmatrix} \quad (4)$$

$$e_{right} = T_{CO}\widehat{e}_{right} \quad (5)$$

$$e_{left} = T_{CO}\widehat{e}_{left} \quad (6)$$

$$T_{OC} = T_{CO}^{-1} \quad (7)$$

$$\widehat{h}_i = T_{OC}h_i \quad (i = 1,\ldots 4) \quad (8)$$

where T_{OC} and T_{CO} are the transformations from the face coordinate system to the camera coordinate system and vice versus, and $\widehat{e}_{right}$ and $\widehat{e}_{left}$ are the eye centers in camera coordinate system corresponding to e_{right} and e_{left} in the face coordinate system. The value of 0.23 is based on the golden ratio of the facial geometry [Pallett et al. 2010] between the distance of the eyes and the ears in a normal looking face. Parameters α and β are used to determine the positions of the four reference points on the user's head. Figure 5 shows a horizontal slice of the head along the eyes and the ears. We assume that it is circular in shape for simplicity and ease of approximate calculations. Hence β is set to be 1 in our current system. The center of the coordinate system, located at the middle of two eyes, is indicated by point O. Inner corners of the eyes are marked as h_1 and h_2, and those of ears are indicated by h_3 and h_4. We assume that the distance d between the corners of two eyes is equal to the eye's length. Then the corner points of the eyes will be at d/2 distance along the curve from O. Therefore the parameters α will be slightly below 0.5. Our experiments showed that the value between 0.4-0.5 for α would give a satisfactory result.

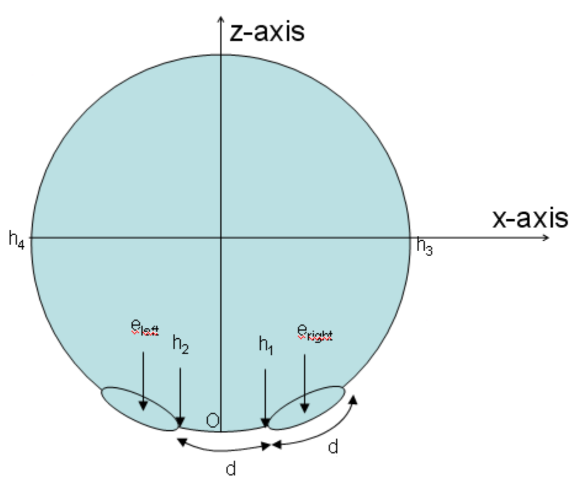

Figure 5. *An approximate human head geometry.*

After obtaining $\widehat{h}_i(i = 1,\ldots 4)$ points, the next step is to estimate the transformation matrix which fits the glasses to the face for each incoming frame. Here we first scale the vertex coordinates of the glasses using the below equation:

$$scale_x = scale_y = scale_z = \left|\frac{(\widehat{h}_{1x} - \widehat{h}_{2x})}{(p_{1x} - p_{2x})}\sigma + \frac{(\widehat{h}_{3x} - \widehat{h}_{4x})}{(p_{3x} - p_{4x})}(1-\sigma)\right| \quad (9)$$

Based on our experiments we have conducted, we set σ to 0.15 in Equation (9) as the distance between $\widehat{h}_1$ and $\widehat{h}_2$ along X-axis is significantly shorter than the distance between $\widehat{h}_3$ and $\widehat{h}_4$. Next, we need to find the best fit the four points $p_i(i = 1,\ldots 4)$ on the glasses to $\widehat{h}_i(i = 1,\ldots 4)$. We use a standard non-linear optimization method to estimate optimal parameters R_x, R_y, R_z (rotations along X, Y, and Z-axes) and t (translation) which transform the four points $p_i(i = 1,\ldots 4)$ on the glasses to $\widehat{h}_i(i = 1,\ldots 4)$ on user's face. In this case, there are 6 unknowns (3 for rotation and 3 for translation) and 12 equations. The optimal parameters are estimated using the Levenberg-Marquardt (LM) method with a proper starting point. In the LM method, the optimality is defined based on the minimization of the sum of square of the distances between $\widehat{h}_i(i = 1,\ldots 4)$ and the transformed four points $p_i(i = 1,\ldots 4)$ using the following equation:

$$\arg\min_{R,t} \sum_{i=1}^{4}\left[\hat{h}_i - (P_i * R + t)\right]^2 \quad (10)$$

3.3 Occlusion Handling

When the user turns his/her head in various viewpoints, there is an occlusion problem for the virtual glasses try-on system. As shown in the region indicated by the red circle in Figure 6(a), the right arm of the glasses is displayed improperly on the screen and the user would not have a feeling of realism.

In this section, we describe a simple occlusion solution using the screen coordinates of related vertexes on the glasses. The screen coordinates for a given object-space coordinate (coordinate in the face coordinate system in this paper) can be found given the model view matrix, the projection matrix, the viewport and the input face space coordinates.

Let's consider the left arm and investigate if it is occluded by the main frame. We denote the vertex on the left arm and its corresponding screen coordinate as V^i_{larm} and S^i_{larm}. As we already know the coordinates of { p_2, p_8, p_6, p_{10} }, we calculate their screen coordinates, denoted as { S_2, S_8, S_6, S_{10} }. Occlusion of the vertex on the left arm of the glasses can be determined the following rule:

$$vertex\_on\_leftarm = \begin{cases} 1 & if\ S_{2x} \le S^i_{larmx} \le S_{6x}\ \ and\ \ S_{10y} \le S^i_{larmy} \le S_{8y} \\ -1 & otherwise \end{cases} \quad (11)$$

Here, "1" and "-1" indicate if the vertex is occluded or not occluded, respectively. Similar rule can be applied to the vertices on the right arm. If certain vertices of the left or the right arm are occluded by the frame, the respective arm is not displayed on the screen in our system. Figure 6(a) shows the result without occlusion handling, where the left arm is occluded by the frame but is still shown. After applying the proposed occlusion handling method, the left arm is not shown on the screen, as can be seen in Figure 6(b).

4 Experiments

Our system has been implemented as a virtual try-on mirror system for installing at retail shops. It uses a dedicated PC and high resolution camera, and has been shown in Figure 2. A down-scaled version has been implemented on a laptop with a normal webcam as well. The larger system is for installing at the retailer's site, while the latter is intended for online shopping. The user standing in front of the larger system, or sitting in front of the laptop, can select from large number of glasses models. Some examples have been shown in Figures 7.

(a) (b)

Figure 6. *Examples of the occlusion problem.*

In our current implementation, we need to manually specify four reference points on each pair of virtual glasses in the offline stage. We are working on techniques for automatic recognition of these reference points for various virtual glasses models to enable users to add their 3D virtual glasses model to our system data base easily. It should be also noted that when the person already wears a pair of glasses with thick frames, the physical frames will affects the realism of the augmented virtual glasses. We are also working on automatically recognizing the physical frames on the user's face and removing it using related image completion technology [e.g. Komodakis and Tziritas, 2007]. Hence, even the user already wears a pair of glasses with thick frames, the virtual glasses try-on results will still look aesthetically realistic on his/her face.

Figure 7. *Examples of the virtual glasses try-on system.*

5 Conclusions

In this paper, we present a mixed reality system for virtual glasses try-on system which enables the user to see different models of spectacles fitted on his/her face in correct pose. The system does not require any manual initialization and can scale and orient to face size and orientation as far as the face is within the camera view. The system has two versions. One is integrated into our virtual mirror system and the other is just run on any computers or notebooks with built-in camera. It has been shown and tested in several public events and we received positive comments from the visitors. This system has a great commercial potential in the eyewear market.

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