Augmented Rendering of Makeup Features in a Smart Interactive Mirror System for Decision Support in Cosmetic Products Selection

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***Abstract*—We propose a smart mirror system to display an augmented 3D representation of the user with makeup features. In this approach the user is able to view the possible outcomes of different makeup applications in the smart mirror without affecting the real face appearance in the process. The system incorporates 3D face construction, IR based face tracking and OpenGL material extensive rendering approach to deliver the augmented made-up face. We argue that by viewing the augmented grooming features the users will be able to flexibly decide the makeup products of their choice.**

***Keywords*-Smart mirror, human computer interaction, face tracking, rendering, augmented visualization.**

I. INTRODUCTION

We propose a smart interactive mirror system and present its benefits in decision support for cosmetic product selection. This is an attempt to contribute to the design of a real mirror system in which the interface is used for virtual application of makeup products. Makeup product selection is challenging [1] [2]. There are different kinds of makeup products and there has been an explosion in the number of makeup brands. Also, there are many different shades/colors for the eyelashes, mascara, nail-polish, lipsticks etc in a store that makes the makeup selection process overwhelming to the user. Moreover, in order to select a makeup product the user often needs to be assured that its application will suit her skin tone etc. In this motivation, we present a sensory augmented smart interaction mirror (SIM) system, where the user will be able to apply different makeup products on his/her virtual 3D face in a natural way and see the results. Research in this direction has addressed the development of smart augmented mirror [3][4][5], cosmetic apparatus [6], half mirror [7], smart picture frame, and so on [8]. The development of smart makeup mirror may be considered as the realization of bridging the gap between virtual and real environment [9][10]. Our work is geared towards this direction and is focused on the design and development of a smart mirror interface for makeup selection.

The application of SIM may provide convenience, efficiency, and usefulness to its users [1] in cosmetic product selection. The system can help in providing cheaper alternatives to the different makeup products. Therefore, the design of SIM for make up selection should not be only cosmetic-driven, but also it should consider other aspects of product purchasing with a view to providing cheaper and alternative product recommendations.

Our contribution in this paper is three-fold. First, we present 3D rendering and interactive display of makeup features that can provide decision support for cosmetic products selection. Second, by incorporating IR based motion tracking technology we approximate the user's mobile position with respect to the smart mirror screen and calculated the approximate distance of the user from the screen. Third, we provide recommendation to the user of similar and cheaper makeup products.

The remainder of this paper is organized as follows. In the beginning, Section II illustrates smart interaction mirror system, where we discuss basic camera arrangements, and IR based distance measurement algorithm. Further in Section III we describe the product recommendation scheme in details. System details, implementation issues and results are described in Section IV. At the end in we have provided some conclusion and possible future work guidelines in Section V.

II. SMART INTERACTION MIRROR SYSTEM

In this section we present the smart interactive mirror system and illustrate its components. In the beginning the overall system setting is described in section II-A. Later in section II-B we present the Infra Red (IR) camera parameters and hand motion tracking scheme. Furthermore, in section II-C we present the facial orientation and distance (proximity) determination technique and present algorithms and mathematical details. Illustration about the user texture based 3D face rendering is discussed in section II-E. Lastly in section II-F we present the makeup products' texture and material processing technique in detail.

A. System setting

We present the system hardware configuration and usage settings in this section. The overall configuration of the system is depicted in Figure 1. The system is comprised of an array of sensory devices. We used an IR camera in order to track the face and hand movements of the user. In order to obtain the product rendering configuration an RFID

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tag was attached with each mock product. When the user wants to select a product for application s/he needs to scan the mock product in the reader located beside the mirror. The system reads the tag and prepares the texture and material based 3D rendering of the product.

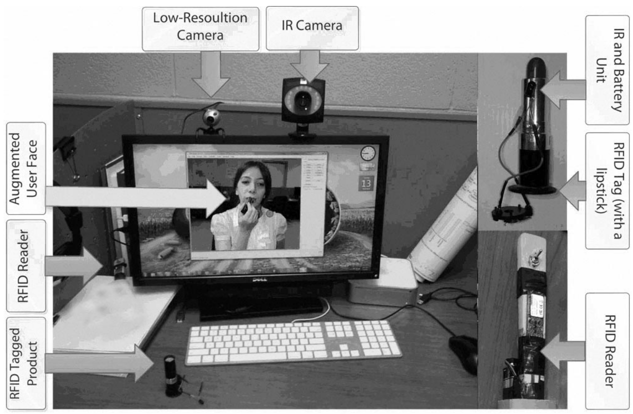

Figure 1. System hardware configuration.

In order to track the product movements an IR emitter was placed on each product along with a small battery unit to power the emitter. We added Bluetooth hardware in the RFID reader so that the reader could be placed conveniently. In our system, a digital 21 inch monitor mimics a mirror.

B. IR based hand motion tracking

In this section we discuss the properties of a single IR camera. As depicted in Figure 1, an IR camera was placed on top of the mirror screen to track the IR emitter placed in the mock product unit. IR emitter node is a small LED that emits IR signal that is then captured by an IR motion tracker camera. The IR capture interface of the camera captures a noise free image of the IR emitter node and calculates its 2D position with respect to the image boundary. In our previous work [11] we have experimented that capturing the motion points of an IR emitter node in a 2D space is fairly accurate.

C. Face distance and orientation determination

We fitted two IR emitters in the user's ear-pins. Based on the position of the calculated position of these emitters we determined the approximated distance of the user from the mirror screen. In this scheme, the IR camera positions and offsets from a known reference point in the environment were calibrated in advance. In order to obtain the approximated depth of the user the Algorithm 1 was incorporated. The technique behind the 3D depth approximation is explained in Figure 2. To illustrate, let us assume that the physical distance of the two IR emitters placed in the user's ear-pins was δ. When the user was at a close proximity of the mirror screen the projected distance between the two IR emitters was $\partial x = abs(x_R - x_L) \approx Z_0$. Hence, the distance of the user's face was now proportional to the ratio of the IR emitters projected screen distance to their real world physical distance, which was given by $Z \approx Z_0 \frac{\delta}{\partial x}$. Therefore, by using the stereo vision methodology [12] we designed algorithm 1 to calculate the approximated 3D depth position of the user's face.

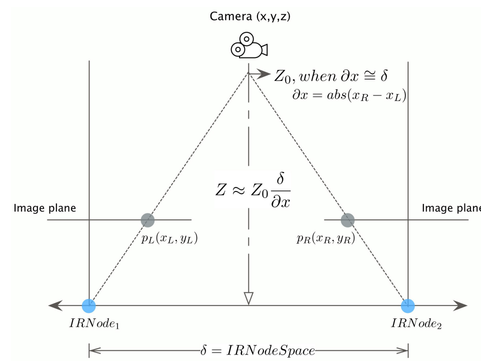

Figure 2. Approximated depth position estimation of the IR emitters.

Algorithm 1 Calculate $Z \approx Z_0 \frac{\delta}{\partial x}$ and Approximate 3D mobile location

Require: $Z_0, when\, \partial x \cong \delta$ /* ∂x becomes 0 when the two IR nodes are very far from the screen. Hence, benefit of the scheme can only be realized in indoor environments. */
Ensure: $\partial x \neq 0$
Set $Z_0, when\, \partial x \cong \delta$ /* Z_0 is an application specific variable */
Determine the states of the $IRNode_1(x_L, y_L)$ and $IRNode_2(x_R, y_R)$ from the IR Camera by applying the scaling transformations.
Calculate $\partial x = abs(x_R - x_L)$
if $\partial x \neq 0$ **then**
    Set $Z \approx Z_0 \frac{\delta}{\partial x}$
else
    Set $Z \approx Z_0 * \delta$
end if
return $p(X = \frac{x_L + x_R}{2}, Y = \frac{y_L + y_R}{2}, Z)$ as the approximated 3D mobile location.

D. Face tracking scheme

In order to map the interaction point of the depth image coordinate to the touched points of the users skin coordinate, we setup the 3D face geometry that emulates the user face. Marker detectors were used to track the movements of the user and calculate the orientation of the virtual face. The virtual face was managed by the human model manager and transformed into the depth image coordinate. As a result, the virtual face emulated the features of the user's face and responded to his/her movements. The alignment of the user's face was determined from the alignment of the two IR emitters. The connecting point of the two IR emitters formed a line and when compared with the reference point of the IR camera the angle of the user's face was determined.

E. 3D face rendering

Our 3D face construction was off-line and used the frame work provided by [13]. In order to construct the 3D face we first generated the texture for the user by blending three different angled photographs of the user's face. Afterwards by processing the 2D features of the user's face we deformed a basic face model to approximate the user's face geometry. The user's texture was subsequently uv mapped in the model for rendering. The model's geometry was grouped according to different facial parts. The eyebrows, lips, nose, chins, foreheads, and eyelashes were grouped. This grouping improved the geometric deformation process that used the user's 2D facial features. Moreover, when the user scaned any product, appropriate 3D facial group was considered for the cosmetic product rendering. For example if the user selected the lipstick the 3D lip geometry of the 3D face was considered for the lipstick texture and material based rendering.

F. Texture and material property of a cosmetic product

We created database entry for each product and stored the product's texture, material and face geometry group information. The texture property was used in order to augment the deformed 3D face by adopting the multi-texturing technique. The texture property of the cosmetic products defined the feel and appearance of a surface, especially how rough or smooth it was. The product and the facial textures were alpha-blended in order to create the realistic makeup face. By using the material property we defined the emission color of the resultant facial features. Also, the intensity of the fractal color was corrected. Lastly by using the material property the shininess (specular exponent of the material) of the face geometry was adjusted as needed.

III. Product Recommendations

One of the major goals of this research is to propose recommendations based on the usage statistics of different cosmetic products. Based on the history statistics and the products features, the system calculated different recommendations and showed those with pictures and touch links on the bottom of the mirror screen for navigation. These recommendation approaches are discussed briefly in the following:

- In this recommendation scheme the system tracked the type of products that the users chose to interact with and created rank on their usages. For example if the user selected a lipstick then lipstick products of different brands were considered for recommendation.
- The recommendation system looked up the texture and type of the current product and delivered information of similar products of different brands. When products were searched in this scheme price was considered as the main metrics for sorting. Hence, products containing similar features were displayed along with their price information.
- Complementary products were those that goes with the original product. For example, lip-gloss is a complementary product for the lipstick and vice-versa. In order to provide the recommendation the system carefully analyzed the product information and queried the database for the link information. These links were created in the product database when new products were entered into the system. The system analyzed the links and created the complementary product recommendations by considering the current product features the user was navigating.

IV. Implementation and Result Study

We present the implementation issues of the system in Section IV-A where we discuss different tools and interface that were used in our SIM system. Later in Section IV-B we describe usability study of the system that were performed using the implemented prototype system.

A. Implementation issues

In this section we present the details about the implementation issues and illustrates the software and tools that were used in the smart interactive mirror system. The system was developed using Microsoft Visual Studio 2008 with dot net support and primary programming language used was Visual C#. The RFID reader interface and the IR camera-tracking interface were also implemented in this environment. In order to render the 3D model OpenGL graphics library (version 1.3) had been used in our system. In order to track the face of the user we experimented both with IR emitter tracking and AR Toolkit based tracking approaches. Amongst the two, IR emitter based facial orientation and transformation calculation showed promising results in our implementation.

B. Usability study

The usability tests took place at the university laboratory in a controlled environment with five participants. We briefed each participant about the purpose of the study and how it would be organized. We also showed the video on how to scan, switch on and apply the product features using the mirror screen and create different makeup possibilities. After that we conducted the actual evaluation by consecutively handing out a sheet of paper describing the current task the participant had to carry out with the system. After all tasks had been completed we conducted an interview with

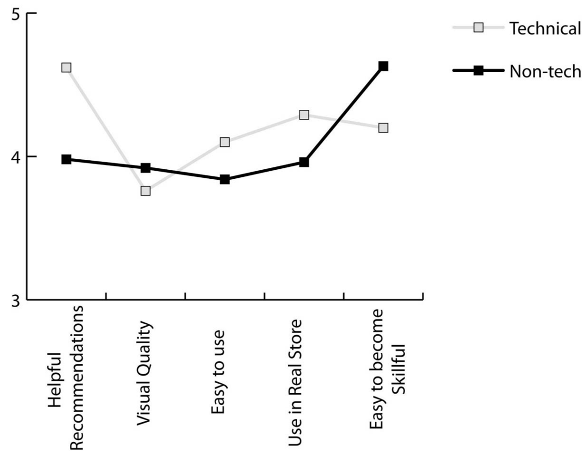

Figure 3. Usability study of the proposed SIM system.

the users. We also asked open-ended questions about their perception of the system's usability.

In the end of the experiments the participating users were told to fill out a questionnaire and to rate (in Likert scale [14]) some given assertions according to their usage experience of the system. The average of the responses of the users were recorded and studied to prepare the results. The users were categorized into two groups. Participants of one group had technical background and conducted usability experiments previously. When determining the usability parameters of the system we focused on the aspects to find out whether the system was sufficiently easy to use and particularly do not exclude any user in the process. In our study we found that the users consented that mirror interaction was understandable and that the provided recommendations were intuitive to follow. However, the users were unhappy about the visual quality of the system. In Figure 3 the assertions and the user responses of the two groups are presented.

V. Conclusions

We have presented an interactive mirror system, where the user is able to see the augmented representation of his/her along with the result of the application of different cosmetic products. The proposed smart mirror system provides convenience, and usefulness to its users in cosmetic product selection. By using IR emitter tracking approach we were able to accurately determine user's face orientation and distance from the digital mirror screen and leveraged these parameters in the rendering of the approximated 3D face geometry. Moreover, by employing usage based recommendations the system assisted in providing cheaper alternatives to the different makeup products to the user. In our usability study of the prototype system we found out that the system was appreciated by the user for its ease of use and helpful product recommendations features.

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