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Research paper

3D projection mapping for facial cosmetic surgery by creating a 3D video

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Abstract

Due to the rapid growth of technology, millions of systems are designed day by day to fulfill their duties in facilitating the human lives. In this paper, the projection mapping method is used to help users who need to do facial cosmetic surgery in taking the right decisions by providing them with a unique system, which can be used in cosmetic surgeries' clinics. The main purpose of the system is to make a projection mapping on a face model that presents the changes that need to be applied on the face features with some facial expressions, as a result, the user will be able to compare between his/her face before and after the surgery and take the certainly decision. A suitable web based UI is created to make it easier for the user by enabling him/her to choose the needed surgery and come up with his/her own projection mapping video.

Keywords: *3D Projection Mapping; 3D Face Model; 3D Video; Cosmetic Surgery; Facial Effects.*

1. Introduction

During the past decades, presentations were limited to only regular and static presentations that are projected on flat screens to present any idea, yet nowadays practical life requires new and unique ways to help increasing the businesses incomes other than the classic ways that started to be boring due to its similarity. Therefore, technology introduced 3D projection mapping to catch the attention from the objective clients in a very interesting way, and to serve different types of users.

Projection mapping has many alternate names including the original academic term "spatial augmented reality" and "video mapping" [1]. It is the technique that instead of using a projector to present a regular presentation on a flat screen, it uses an entire object (sometimes an architecture) as the screen by mapping the projector's lights onto the surface in order to turn this 3D shaped object into an interactive display.

Historically, Anamorphosis [2] can be considered as the very old projection mapping. It's a technique that was available before there were digital pixels; artists used it to make the subjects of their paintings looks like they're jumping out of the frames. Anamorphosis depends on projection tricks that make the image appears 3D from exactly one location. However, if you moved slightly in any direction, the illusion is lost. Projection mapping does the same idea but with animation techniques and without losing the illusion in any direction.

First, projection mapping was initiated as a new eye-catching way to deliver the artists and researchers' ideas and to interpret architecture. Later, marketing adopted this technique for branding, with large-scale projections on towers and skyscrapers. Yet now, this technology can be applied in every single object no matter how small is the size or how complicated is the shape of the object. Only one thing to be considered is the reflectance of the surface that should be high for a good visibility of the projected images, the reason why glass façades with their mirroring effect, and black surfaces, with their low reflectance, are not useful for this type of projection.

Projection mapping technology can be used by different types of users; artists, programmers, advertisers, and event organizers. It is needed in a wide variety of fields; advertisements, face-hacking, in-house celebrations and events decorations [3], live concerts, theatres performances, Scientists experiments, education, gaming, and computing. The most popular use of projection mapping is advertising, which can include fashion shows to advertise for clothing companies, movie tutorials, or announcements for upcoming events. Face-Hacking [4] is a technique used by movie directors that replaces the traditional makeup and masks with visual makeup by projecting the effects on the contours of the actors faces. In addition, inventors and programmers are adapting this technology for their new inventions such as projection watches or mobile phones that depends on lasers as skin buttons [5].

The goal of the proposed system is to introduce projection-mapping services towards cosmetic surgeries. That's achieved by developing a 3D video of the early results of any cosmetic surgery the user can choose, and projecting the video on a gypsum face mold. The video contains visual animation effects that show the pre-post changes of the desired surgery.

2. Proposed system

The proposed system can be considered by any medical clinic that is willing to use it. Until now, patients face a risk of the unknown result of any desired surgery. However, when the proposed system is purchased, it will be used effectively and it will gain the customers satisfaction after they see their own before and after look. Most medical clinics follow the same strategy of the interaction with the customers; men, women, teenagers and adults. When customers ask for a surgery to be done, surgeons can show them the expected outcome of the surgery only on the exact organ either by hand drawing

or computerized one, but They cannot imagine if it's going to fit them or not.
The proposed system provides a 3D face model of a person who wishes to perform facial cosmetic surgery. On this 3D face model, the projection mapping is applied to make some changes to the facial features as well as to present different facial expressions with the changed looks. This work can be applied in the medical field before doing the actual cosmetic surgery on the patient/user face. It enables the user to see the final result of any cosmetic surgery he/she is willing to do, and to find out the differences between the face before and after the surgery.

2.1. Need, scope and objectives

The proposed system is developed to overcome the cosmetic surgery drawbacks. It will involve the users by allowing them to choose the face features they want to change, and work to meet their requirements by developing their requested 3D video. This work is needed to help the users in taking the right decisions about their cosmetic surgeries and to avoid any negative consequences that may result.
The scope of this proposed system is to create a 3D video mapping presentation on a face model that can be useful in plastic surgeries' clinics, and to facilitate the patients' decisions in changing any face feature. The main purpose of this system is to help reducing the risk of surgery's consequences that may not match the predicted result. Facial effects will be applied like face expressions and transformation of the face features, which will enable the user to check if the desired change is going to fit him/her from the very beginning of the diagnosis. Animation techniques and graphical effects are applied in the project to help the user to take correct decision.
The system includes:

1) Making a gypsum face mold.
2) Designing the motion graphics and the 3D animated effects.
3) Creating a 3D video of the animation and the visual facial effects.
4) Using a projector [6] to present the work on the model.

And does not include:

1) 4D video mapping in Mid-Air [7] without screens.
2) Real time video mapping [5] on a real face.
3) Any interaction by the user during the projection [5].

The main objectives of the proposed system are to produce an application that helps the users taking their decisions after they see the early result, and to decrease the rates of the unsuccessful cosmetic surgeries.
Those objectives will be accomplished by:

- Creating a 3D video mapping to present the expected outputs.
- Creating a website where users can choose the face features they want to change.

2.2. Modules

2.2.1. 3D face models

This module will include the design of the face mold and the computer-generated face model.
To generate the 3D face model, a property in FaceGen [8] has been used, which allows the user to import a picture of a human face and then it will convert it into a 3D face model that can be exported to other programs [9].

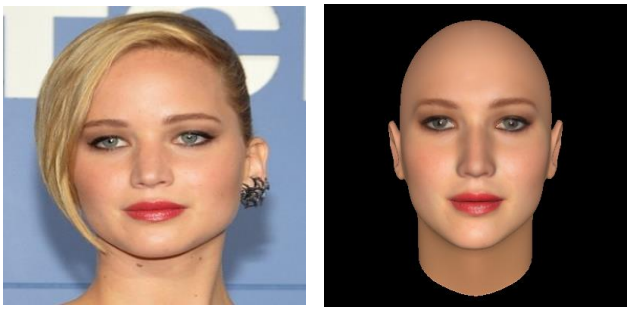

Fig. 1: A) Input, B) Output (Front View) of 3D Facegen

Fig. 1a and 1b show the actual and generate 3D face model from the FaceGen. Only front view of the 3D face model is considered in this work to produce various looks. After designing a 3D face model, 3D face mold is built using gypsum depending on the designed model. A prototype of the face mold will be imported before the actual creation. The final output of this module is the 3D front face mold ready to be used as a screen in order to apply the projection mapping on it.

2.2.2. 3D video

This module includes the process of generating the video that will be mapped to the face mold. In order to create the 3D video, animation techniques are used and visual effects are applied on the 3D face model.
The features are subjected to the different visual effects such as Eye color, Eyebrows, Eyelids, Cheeks, Nose, Lips, Chin and Hair color. The animation will include the facial expressions such as Happiness, Sadness, Fear, Anger, Surprise and Disgust
Each face feature will have its own visual effects and changes. Therefore, its recommended to create separate video including all animation and visual effects with the expressions that might be applied for each of the face features. After creating multiple videos, each for a specific face feature, a full video will combine all the effects of all the face features with the face expressions and the changes applied to them. Since, separate videos are created for each of the features there will be two types of 3D Video generated

1) Partial-effects 3D video:

Separate 3D video with the possible changes that might be applied considering every face features.

2) Full-effects 3D video:

3D video that combines the animation effects of all face features is created.
The generated video is then mapped to the face mold using MadMapper [10] to complete the projection mapping.

3. Implementation

There are two approaches considered to generate 3D projection mapping.

- Approach I: In this approach, static 3D model is used and all the effects are applied on the model by changing its own pixels' directions.
- Approach II: In this approach, the effects will be mapped with the model by capturing the motions of a real face.

3.1. Generating the 3D face model

The 3D face model was generated using FaceGen Modeller [8]. It represents a famous woman's face by processing her front face picture in FaceGen. This face model was used in approach I. The picture was imported to FaceGen, and the main features were selected accurately to know the placement of each of them in the processed 3D model. Fig. 1b shows the generated 3D face model that was used in developing the looks and expressions.

3.2. Developing different looks

Approach I is followed to complete this module, which uses the model of the famous face. The 3D model was imported to Adobe After Effects [9] and the various possible transformations of the face after the cosmetic surgery were applied, which results in the following three different looks

Look I

This look shows thinner lips by decreasing the lower lip's size to make it the same size of the upper one. The nose has been shrunken from both sides to be extremely thin. In addition, the eye color has been changed to be green. The eyebrows became thicker with a blond color. The face became thinner, cheeks were lifted, and a double chin was created. Fig. 2 shows all the changes applied to generate look 1. After that, two expressions were applied to this look: happiness as shown in Fig. 3 and sadness as shown in Fig. 4 in order to see how a person can apply the facial expressions after the cosmetic surgeries.

Fig. 2: Look1.

Fig. 3: Happiness.

Fig. 4: Sadness.

Look II

This look is the closest to the normal look because only slight changes were applied to the face features. Fig. 5 shows how the lips became bigger by filling the upper lip a bit. The nose shape hasn't change much except it became slightly thinner, and the cheeks have been lifted. The eyes were made bigger and more circular, their color has changed into light brown and eyelashes extensions were added. The eyebrows turned into thicker and shorter brown eyebrows with almost straight shape. After that, two expressions were applied to this look: fear as shown in Fig. 6 and surprise as shown in Fig. 7.

Fig. 5: Look1.

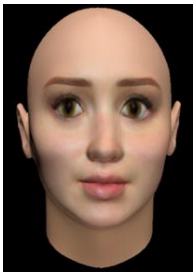

Fig. 6: Fear.

Fig. 7: Surprise.

Look III

This look can be named "fish face" look as shown in Fig. 8, where the lips has been transformed into a fish lip shape by zooming in the sides of the lips and filling both with removing the curve that is in the middle of the upper lip. The eye color became grey and the eyebrows became black, thick and curvy eyebrows. The upper side of the nose has been shrunken, and the lower side has been extended a bit, and finally the face became thinner. After that, two expressions were applied to this look: anger as shown in Fig. 9 and disgust as shown in Fig. 10.

Fig. 8: Look III

Fig. 9: Anger

Fig. 10: Disgust

3.3. Feature extraction

In order to use approach II in the project, feature extraction technique should be applied on a sample face to track the motion of the key face features. The face is divided into two sections:

- Upper part (UP): it includes the forehead, eyebrows, and eyes.
- Lower part (LP): includes the nose, cheeks, mouth and chin.

Points were drawn on the face based on the muscles' movements during any expression. Each face feature will be marked by those points, which were drawn in a symmetrical way for both of the vertical and horizontal aspects. The points that are related to the eyebrows are the only asymmetric points, because each eyebrow has a different shape by nature. Therefore, one of the eyebrows has its points drawn slightly lower than the other ones' as shown in Fig. 11.

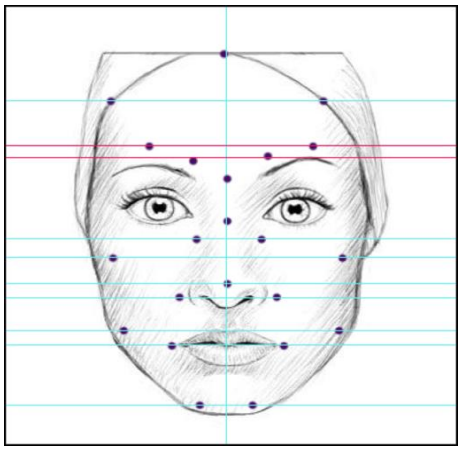

Fig. 11: Feature Extraction: Alignment of Drawing Points.

In order to track the movement of each muscle in every expression, the points were numbered [11] as shown in Fig. 12 below.

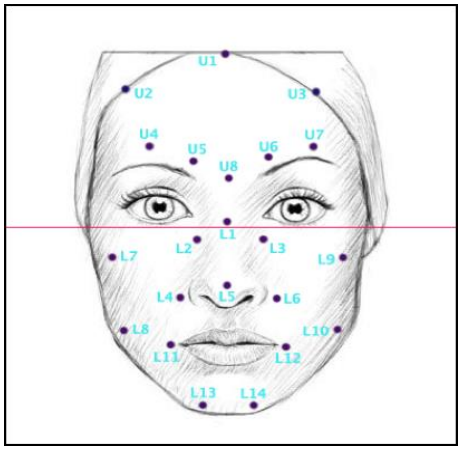

Fig. 12: Feature Extraction: Numbering Points Drawn on the Face.

Table 1 shows the movement directions for each point in every expression using the arrows. The first three points of the upper parts of the face: U1, U2, and U3 were not used in any expression. However, their existence is very important because it affects the stability of the face model after mapping it with the real face in the video.

When the puppet pins stick on those points, this will prevent the upper part of the face from the random movement while the other points are moving with the trackers.

Table 1: Movement of Points on the Face During Expressions

Points	Happiness	Sadness	Fear	Surprise	Anger	Disgust
U1	-	-	-	-	-	-
U2	-	-	-	-	-	-
U3	-	-	-	-	-	-
U4	-		-			-
U5	-					
U6	-					
U7	-		-			-
U8	-				-	
L1	-	-	-	-	-	-
L2	-	-	-	-	-	
L3	-	-	-	-	-	
L4			-		-	
L5	-	-	-	-	-	-
L6			-		-	
L7			-	-	-	-
L8						
L9					-	-
L10		-	-	-		
L11						
L12						
L13					-	-
L14					-	-

Up

Down

Top Right

Top Left

Bottom Left

Bottom Right

Curved Left Up

Curved Right Up

Curved Left Down

Curved Right Down

3.4. Applying facial expressions

The 3D model was imported to Adobe After Effects [9] after applying the look changes on it, look II was chosen to apply the six facial expressions on it (Happiness, sadness, fear, surprise, anger, and disgust). Fig. 13 shows how approach II is followed to complete this module, where the real face's motions are captured and it's extracted features are mapped with the 3D model's features. A video of the real face expressions with the points on the face was recorded before mapping it with the model. The feature extraction techniques that were explained in the previous sub section were used to draw the points.

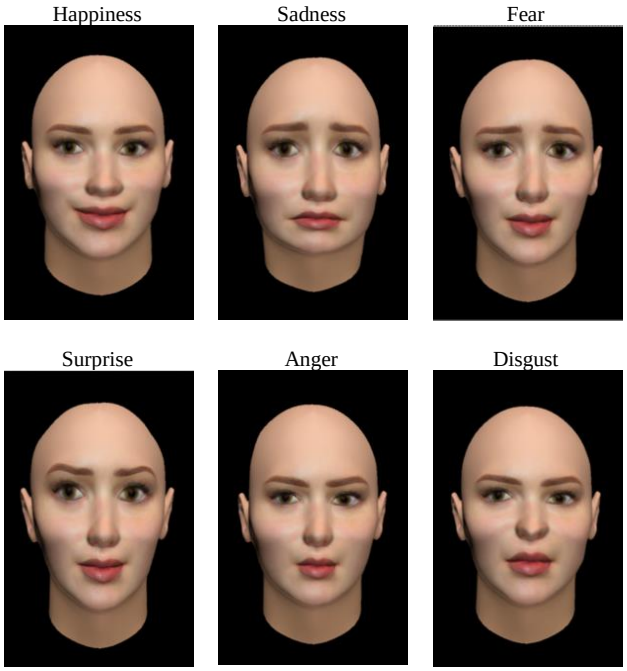

Fig. 13: Approach Ii: Facial Expressions.

3.5. Projection mapping on 3D face mold

After completing the videos of the three looks and expressions, one combined video is generated to project against the 3D face mold, as which is covered with fabric as shown in Fig. 14.

Fig. 14: Face Mold.

MadMapper [10] was used to control the projected area. The lights of the projector cover only the face mold and the hair. Some effects were also applied in MadMapper to show the look and approach numbers on the background wall during the projection time. The duration of the final projection show is one minute and 49 seconds. Fig. 15, Fig. 16, and Fig. 17 show the use of projection mapping technique in presenting the video.

Fig. 15: Scene 1 of Projection Mapping on the Face Mold.

Fig. 16: Scene 2 of Projection on the Face Mold.

Fig. 17: Scene 3 of Projection on the Face Mold.

4. Challenges

During the implementation phase, many challenges are addressed. All the challenges are listed with their causes and the solutions that were taken to resolve them as shown in Table 2.

Table 2: Challenges, Causes and Solutions

Challenge 1: The feature extraction		
Problem	After applying the feature extraction, it was clear that the mouth is cut from the model, which made the surprise expression not applying appropriately.	 **Fig. 18:** Masking Problem.
Cause	The masking that was applied to the mouth for the surprise and fear expressions was not moving appropriately with the movement of the mouth while opening and closing. The reason that made it looks like it's cut from the model.	

Solution	It was decided that the surprise expression can be made without opening the mouth and with changing the eyes and eyebrows only.

Fig. 19: Masking Solved.

Challenge 2: The face mold

Problem	The faces look different when they are projected to the face mold, and the changes are not displayed clearly.

Fig. 20: Face Mold Problem.

Cause	The features of the face mold are affecting the features of the 3D face model, which is giving the 3D model a different look.
Solution	Hiding the features of the face mold so that only the 3d model's features will be displayed without any changes. The face mold was covered with fabric making all the features disappear.

Fig. 21: Face Mold Solved with Fabric Cover.

Challenge 3: The hair of the mold

Problem	The hair of the face mold is not visible during the projection with all the darkness.

Fig. 22: Hair is Not Displayed.

Cause	The lights of the projector located towards the face only and nothing else.
Solution	Creating a new quad [10] with the shape of the hair so that the light can be directed exactly to the hair.

Fig. 23: Hair Problem is Solved.

Challenge 4: The position of the faces

Problem	When transferring from one look to the other, the projection show is distracting because of the wrong placement of the next look, which is leading to changing the projector's position during the show.

Fig. 24: Face Position Changed When Transferring to Scene 2.

Cause	The three combined videos have different position values for the 3D face mold, which make a variable placement for the face after combining the videos together.
Solution	The face models were given the same position values, and then they were combined all together again.

Fig. 25: Position of the Face in Scene 2 is Correct.

5. Conclusion

This paper discussed about the system that can be used in cosmetic surgeries' clinics to help the users taking the right decisions about any surgery they are willing to do, using 3D projection mapping technique to present the early -before and after- changes that are predicted to happen. Initial investigations were carried out on the existing projection mapping. During the investigation and further analysis, the drawbacks of each work were identified to be overcome.

In this paper, the 3D face model was designed and the changes in the face features were applied using visual effects and animation techniques to create three different looks that were summarized in Table 3, and six main expressions that were summarized in Table 4. Two approaches were followed to apply the expressions, one of them by using the pixel changing tools, and the other by the feature extraction technique. A final video containing all the looks and expressions from the two approaches was created. In addition, 3D face mold was used for the projection show. The resulted video was imported to MadMapper and projected against the face mold.

In the future, the constraints that were limiting this proposed work can be overcome. A real-time projection mapping can be used on a real face instead of a face mold. This way, the projection can be also interactive in a way that when the real face applies a certain expression, the projection will be affected and the features will respond to the movement of the real face. Other parts of the human body can also be included. In a wider direction, this project will be used as a reference for any use of projection mapping technique. Some expectations are there for using it in other fields like events, advertising, education, decoration, and projection mapping shows on famous building to encourage the tourism.

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Table 3: Summary of Face Feature Changes in Each Look

Features	Changes Look I	Look II	Look III
Lower lip size	Decrease	–	–
Upper lip size	–	Increase	Increase
Lip curves	Increase	Increase	Decrease
Mouth width	Decrease	–	Decrease
Nose length	Increase	–	Decrease
Nose width	Decrease	Decrease	Upper side: decrease Lower side: increase
Cheeks size	Increase	–	Increase
Cheeks position	Lifted up	Lifted up	–
Eye color	Green	Light brown	Grey
Eye width	–	Increase	–
Eyelashes length and thickness	Increase	Increase	Increase
Eyebrows color	Blonde	Brown	Greyish black
Eyebrows shape	Neutral	Sharp	Curvy
Eyebrows thickness	–	Increase	Increase
Face fats	Decrease	–	Decrease

Table 4: Summary of Muscle Actions in Each Facial Expression Using Both Approaches (+: Increase; -: Decrease)

Expression	Muscle Actions
Happiness	Stretch up corner lips (+) Lift cheeks (+) Stretch down chin (+) Stretch down corner lips (+)
Sadness	Raise inner corners of eyebrows (+) Squeeze eyebrows (+) Lift cheeks (-)
Fear	Raise inner corners of eyebrows (+) Squeeze eyebrows (+) Lift cheeks (-) Stretch down chin (-)
Surprise	Raise eyebrows (+) Lift cheeks (-) Stretch down chin (-)
Anger	Squeeze eyebrows (+) Raise eyebrows (-) Squeeze mouth (+)
Disgust	Squeeze eyebrows (+) Raise eyebrows (-) Squeeze mouth (+) Squeeze nose (+) Lift lower side of nose (+)

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