

## **Design of a Facial Prosthesis**

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### **Abstract**

Facial disfigurement may be caused by many different reasons. By using facial prosthetic device, a patient can avoid uncomfortable experiences. For creating customized prostheses, computer aided design, surface scanning and rapid prototyping technologies are widely used. Now, laser scanner is mostly used as data capturing device. By using that data, it is possible to develop a prosthetic device with the help of surface modeler and fabrication system. But, success of a prosthetic device depends on its aesthetic look and matching capability with facial contour. In this project, a nasal prosthetic device has been tried to develop using laser scanned face data and Rhinoceros 3.0 as a surface modeler. Different surface analysis tools used for critical evaluation of the device. After discussing the problems faced during different designing stages, some suggestions are given for further improvement of the device.

### **Keywords**

Facial Prosthesis, Facial contour, Surface Modeling, Laser Scanner

## **1. Introduction**

### **A. Facial Prosthesis**

Facial prosthesis is a device used to restore a missing or distorted facial feature [1]. The Prosthesis is a custom sculpted device made of silicon that is worn on the top of the skin to restore normal facial contours. It is not uncommon to meet people who unfortunately had some degree of facial deformities or disfigurement, The cause of such mishap could be accidental from work, spread of diseases that require the segregation of healthy tissue from malignant tissue, or congenital facial deformities that disallow a person to have a normal facial anatomy [6]. Different types of facial prosthesis are- orbital(eye and eye lids), nasal(nose), auricular(external ear), hemi facial(eye and cheek), mid facial( nose and cheek) and maxillofacial(nose, cheek and eye).As a result of cancer, trauma, accidents, burns or birth deformity, a person wants to use prosthetic device. Facial prosthetic device can be manufactured from a wide range of materials - including latex, foam latex, silicone, and cold foam [2]. Facial prostheses are mostly made of flexible rubber called silicone. They are designed to cover, protect, and disguise any disfigured or underdeveloped area of the face. Prostheses are designed to have comparable form and function of the natural anatomy. Facial prostheses are used to deceive the casual observer in everyday social encounters such as walking down the street, riding the bus, or shopping at the grocery market [1]. A survey [5] conducted at one Swedish, three Canadian, and 24 United States prosthetic centers reveal that that auricular (72%) region was the most common site in demand, followed by the orbital (20%), nasal (6%), and combination (2%). Though the nasal deformities are less common in numbers, but it is the most crucial as far as the aesthetic expression, dimensional accuracy and precision is concerned.



Figure 1.1: Nasal prosthesis, with deformity (left) and after placing prosthetic device (right)

## 2. Objective and Surface Modeling Tool

### A. Objective

Objective of the current project is to design realistic silicon prosthesis for a facial feature (ear, nose, eye and cheek) such that the inside surface of the prosthesis is contoured to fit the desired facial region. At first, we need to select the facial feature for further work. Then a simulated deformity needs to be created from the selected region of facial feature by removing the data points collected by the CYBERWARE model 3030 head and face scanning system. Those removed points can be used for final prosthetic device analysis. Two-dimensional photograph of the patient can be used as a guide for the curves. Prosthetic device will be compared with the original data to check the fitness with the patient's face. Surface error investigation will be carried out for critical assessment.

### B. Surface Modeling Tool

For designing this type of prosthetic device, surface modeling tool is very important in a sense that it must provide the handling options for surface fitting. NX4, Rhino 3D, Catia etc can be used as a surface modeler for this purpose. But in all cases, output format should be such that it can be easily used for manufacturing purpose. Rhinoceros has been selected for designing this prosthetic device for the following reasons:

- Surface can be generated by using many options like loft, curve networks, revolve, point grids, sweep etc.
- Rhinoceros is the best in editing surfaces. There are editing tools like blend, match, merge that are some of the options which can help in generating and combining the existing surfaces to overcome discontinuities. Fillet, chamfer, offset options can be used to edit surfaces.
- Another important area of Rhinoceros is control point manipulation. Surface can be easily manipulated by using control points, change of degree and addition-removal of knots and kinks. Match, extend, merge, join, split surfaces are other very useful tools in Rhinoceros.

## 3. Description of the Process

### A. Basic Steps

- Scanning my face by using Cyber ware 3030 head and face scanning system.
- Collection of that data in four different formats.
- Using Rhino 3D software as a surface modeler with that collected data.
- Reduction of data from back part of head, upper and lower part of face.
- Nose deformity selection.
- Creation of that deformity by removing data points from selected area.
- Further data reduction from the face.
- Back surface creation (both with hole and without hole).
- Curves creation by projecting lines for the existing part of nose (other than hole area).
- Curves creation for half of the nose hole area.
- Modifying the created curves in reference to the 2D photograph and \*.TIFF image file.
- Mirroring curves for next half of the nose.
- Curves adjustment for full nose.
- Creation of full nose by lofting those curves.
- Matching that nose with surface.
- Performing surface analysis.

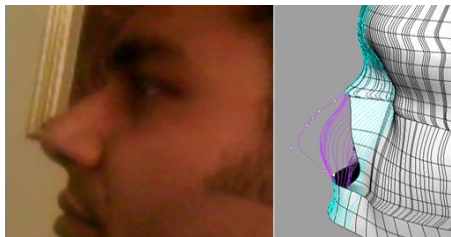


Figure 3.1: Modification of curves

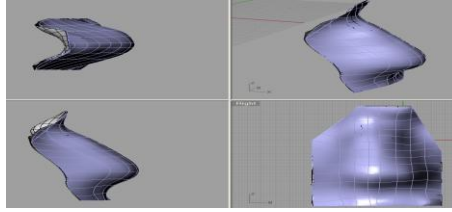


Figure 3.2: Prosthetic device

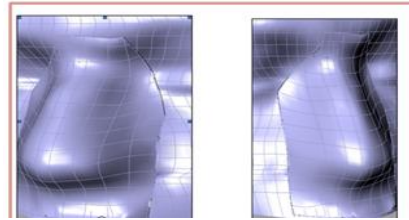


Figure 3.3: Nose matching with back surface

## 4. Surface Analysis Using Rhinoceros 3.0

### A. Surface Analysis by Zebra Stripe

The Zebra command is one of a series of visual surface analysis commands. These commands use NURBS surface evaluation and rendering techniques to help us visually analyze surface smoothness, curvature, and other important properties. In Figure 4.1 we see that both vertical and horizontal stripes are continuous for the prosthetic device. So, smoothness is satisfactory. In Figure 4.2, we see that stripes are not continuing smoothly at the connection of two surfaces. In some cases, stripes are jumped sideways as they cross the connection from one surface to the next. In some cases, they line up but turn sharply at the connection. So, Surface continuity is not satisfactory in this case. It may be the result of trimming those surfaces.

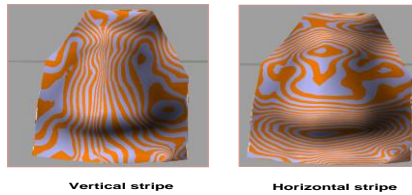


Figure 4.1: Zebra stripe analysis for prosthetic device

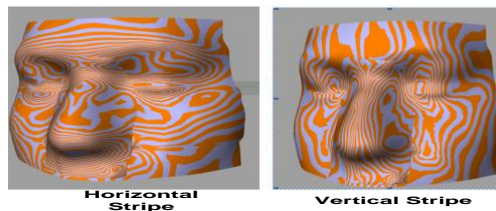


Figure 4.2: Zebra stripe analysis for prosthetic device and back surface

### B. Surface Analysis by Curvature Analysis

The Curvature Analysis command is another visual surface analysis commands. This command uses NURBS surface evaluation and rendering techniques to help us visually analyze surface smoothness, curvature, and other important properties. A smooth surface has two principal curvatures. The Gaussian curvature is a product of the principal curvatures. The Mean curvature is the average of the two principal curvatures. Max radius is useful for flat spot detection. I Set the value for blue 100 and the red close to infinity. Red areas in the model indicate flat spots where the curvature is practically zero. It is shown by Figure 4.3.

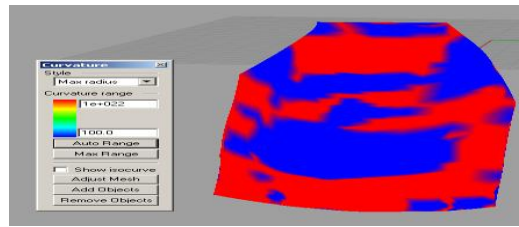


Figure 4.3: Curvature analysis with maximum radius option

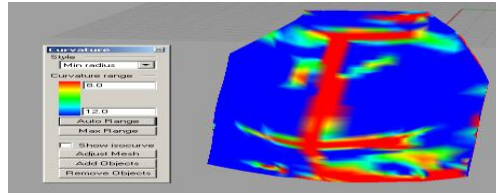


Figure 4.4: Curvature analysis with minimum radius option

Suppose, we are going to mill a surface with a cutting ball of radius  $r$ . Then, any place on the surface that "curves" with a radius smaller than  $r$  will cause trouble. In the case of the mill, our cutting ball will remove material we want to keep. By this method, we can also find out if the surface has any place where it bends too tightly. Here  $r$  is the cutter dia. We need to set, value for red =  $1.5 * r$ . Here I considered cutter diameter as 8mm. It is shown in Figure 4.4. Red colors on the surface indicate that we can't mill in that region. Blue areas should be safe. Areas from green towards red are suspicious.

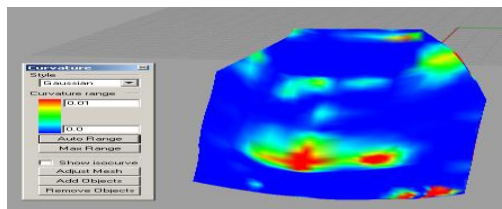


Figure 4.5: Surface analysis using Gaussian curvature

In Gaussian curvature analysis, red region means that surface is bowl like at that portion and curvature is positive there. Blue means saddle like surface and it has a negative curvature. Green means surface is flat at that region and curvature is zero. This is shown in Figure 4.5.

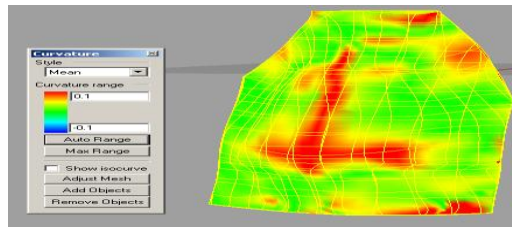


Figure 4.6: Surface analysis using mean curvature option

Mean option displays the absolute value mean curvature. It is useful for finding areas of abrupt change on the surface. This is shown in Figure 4.6. So, based on curvature analysis we can say that still we have some problematic areas on the surface of prosthetic device.

### C. Surface Analysis by Using Point Set Deviation Option

By using this option, generated surface was compared with original nose data points. Curves in the area (Figure 4.7) shown in red color was modified several times. So, compared to original data, this area deviated more. But still standard deviation is 0.83017. It is within the tolerance limit.

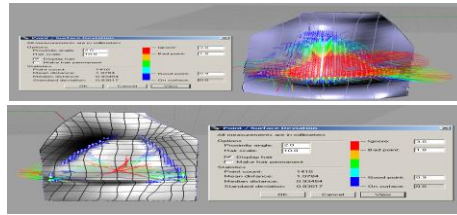


Figure 4.7: Surface analysis by point set deviation

## 5. Problem Area of the Device

### A .Gap between the Internal and External Surface of Nose

Back surface of prosthetic device was created by trimming back surface without hole part. Then, for creating the shape of the device, both surfaces were trimmed again. Then, it was tried to match both surfaces using available options in Rhinoceros. But editing options like match merge work only with untrimmed surface. Gap was more at the upper half of both the surfaces. This is shown in Figure 5.1. Curve bending was more here. As a result of trimming in this area, gap was also more. If we try to use blend surface, then Rhino will create another thin surface between the gap of front and back surface. It can close that gap but surface matching with the facial contour will then be another problem due to higher thickness at the edges.

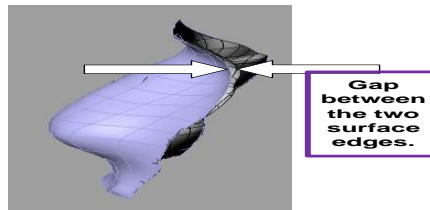


Figure 5.1: Gap between the two surface edges

## 6. Improvement Suggestions and Conclusion

### A. Improvement Suggestions

- For further improvement of the prosthetic device, two holes can be created by projecting object on the surface as shown in Figure 6.1. After projection, those objects can be extruded. Then using difference option for the device surface and extruded surface, we can get those holes. Finally, we need to fillet those holes.

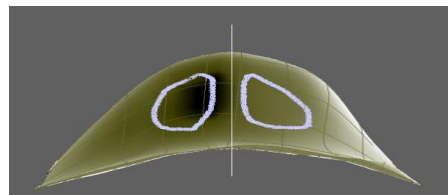


Figure 6.1: Hole making process

- In the existing design, main problem is the gap between the external and back surface of prosthetic device. Actually, trimming is the main source of this gap. Because, Rhino doesn't allow editing any trimmed surface. That is, we cannot match or merge any trimmed surface. We can use blend surface

option. But, as I mentioned earlier, it will create surface matching problem. So, we should try to avoid trimming options. May be we can follow one of the alternative method for generating nose surface. First, we should create horizontal planes in the nose area. Then, creating third degree curves for the nose area on those planes. Next, connecting both sides of the curves, maintaining continuity, manipulating control points and smoothing them. Finally, using loft or curve network, we can generate the surface in such a way that trimming will not necessary at the upper portion of the nose surface.

## **B. Conclusion**

A facial prosthetic device (Nose) has been designed using scanned face data and Rhinoceros 3.0 as surface modeler. The generated model of the nose prosthetic device is not exactly similar to the original nose but it matches fairly in shape and size. Minimum cubic degree curve must be used to represents the curves. This is the minimum degree curve that can generate  $C_2$  continuous curves after matching it with the other curves. The numbers of control points defined to represents the curves and surfaces are altered, added, removed to have better control over the shape of the curve. This one is a good option of generating and altering shapes of the curve and hence surfaces. After surface analysis, improvement suggestions are also given. Little bit problem still we have in the design. After correcting that we should perform the next step of fabrication for the practical use of nasal prosthetic device.

## **Acknowledgements**

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