

7.0 Results

The objective of this research is to optimize the procedure of geometric trimming of any given B-spline surface. As described earlier, if the points at which curvature minimas or maximas occur on a surface are identified, they can be used to make a new surface which can very closely approximate the original surface.

Fleming's constraint based inversion algorithm [Flem92a] [Flem92b] was utilized when interpolating B-spline surfaces through a given set of points. A tool kit developed using the C programming language, OpenGL graphics library functions and X/Motif was implemented in order to visualize the results. C language subroutines were used to determine the approximation errors, while error visualization software developed in MATLAB was used to display and analyze the results. These software were installed on IBM RS/6000 and Windows NT workstations.

Various cases of trimming curves have been tried on surfaces with varying complexity. The data for constructing the surfaces were generated using popular CAD software called I-DEAS 7.0. A set of 21 equally spaced parameter values for the trimming curve were

considered for each case. The data was stored in two separate data files. The surface data files have file names like *datasurf_xx* while the trim curve data files have file names like *datatrimxx*.

One set of results is presented for a case, which can be considered appropriate for reflecting the validity of the given approach. The surface considered does not have a smooth geometry. It has a few ridges distributed over its span and the surface itself spans an area of 2'' x 2''. The results comprise of screen shots of the original surface patch, two trimmed patches (one constructed before surface interrogation and the other constructed after) and their corresponding error plots. Screen shots of the iso-parametric curves that were considered for surface interrogation in each case are also presented. Two versions of the trimmed patch and their corresponding error plots are depicted as part of the results in order to impress upon the reader, the effectiveness of the approach involving trim surface description after surface interrogation.

Among the results presented, the screen shots of the two surfaces displayed together are probably the most intuitive and a less scientific means employed to determine how closely the newly created patch resembles the original untrimmed surface. Screen shots of the images obtained from the visualization tool kit are presented as Figures 7.2 – 7.7, 7.10, 7.11 – 7.15, 7.18, 7.19 – 7.23, 7.26, 7.27 – 7.31, 7.34 and 7.35 – 7.39. Different colors are given for the original and the resulting two trimmed patches. A muddy orange color is given for the original surface while two shades of green are given for the trimmed patches, the lighter shade for the surface after interrogation and the darker shade for the

one before interrogation. The harder it is to distinguish between the two surfaces, the more accurate the results are. The size of the z-buffer can some times hinder this method of differentiation. When two points are very close to each other, round-off errors occur and these are displayed as “noise” on the screen (random spots of different colors appears on the surface). In addition this does not give any numerical estimate of the error.

From the visual analysis, it was observed that the boundary of the newly created trimmed patch closely adhered to the trim curve used in trimming the original patch. This was expected since the location of some of the points at the boundary of the new surface matched their respective values on the trim curve. Also, due to a very high quality rendering obtained by the use of OpenGL’s 24-bit RGBA coloring scheme, areas of discrepancies are easily identified.

In order to obtain a numerical estimate of the error due to approximation between the original and the trimmed patch, “error plots” are generated for all the cases. An error plot is basically a plot of the magnitudes of the vector differences between points corresponding to the same parameter values on the two surfaces [Jain99]. The plot is generated in the $u-v$ plane. Though the error plots are in no way related to the actual dimensions of the two surfaces being compared in Cartesian space, a study of its shape helps the designer to identify areas on the new surface with significant position error. The elevation of the crests indicates the magnitude of the discrepancies.

In order to generate the error plots, a 50 x 50 grid of points were sampled on both the surfaces. This seemed to be an appropriate refinement since it was fine enough to provide with a good number of position difference readings and coarse enough to keep the computational complexity low. Figures 7.8 – 7.9, 7.16 – 7.17, 7.24 – 7.25, 7.32 – 7.33 and 7.40 – 7.41 are the error plots obtained for the cases considered. Figure 7.1 shows the cases considered.

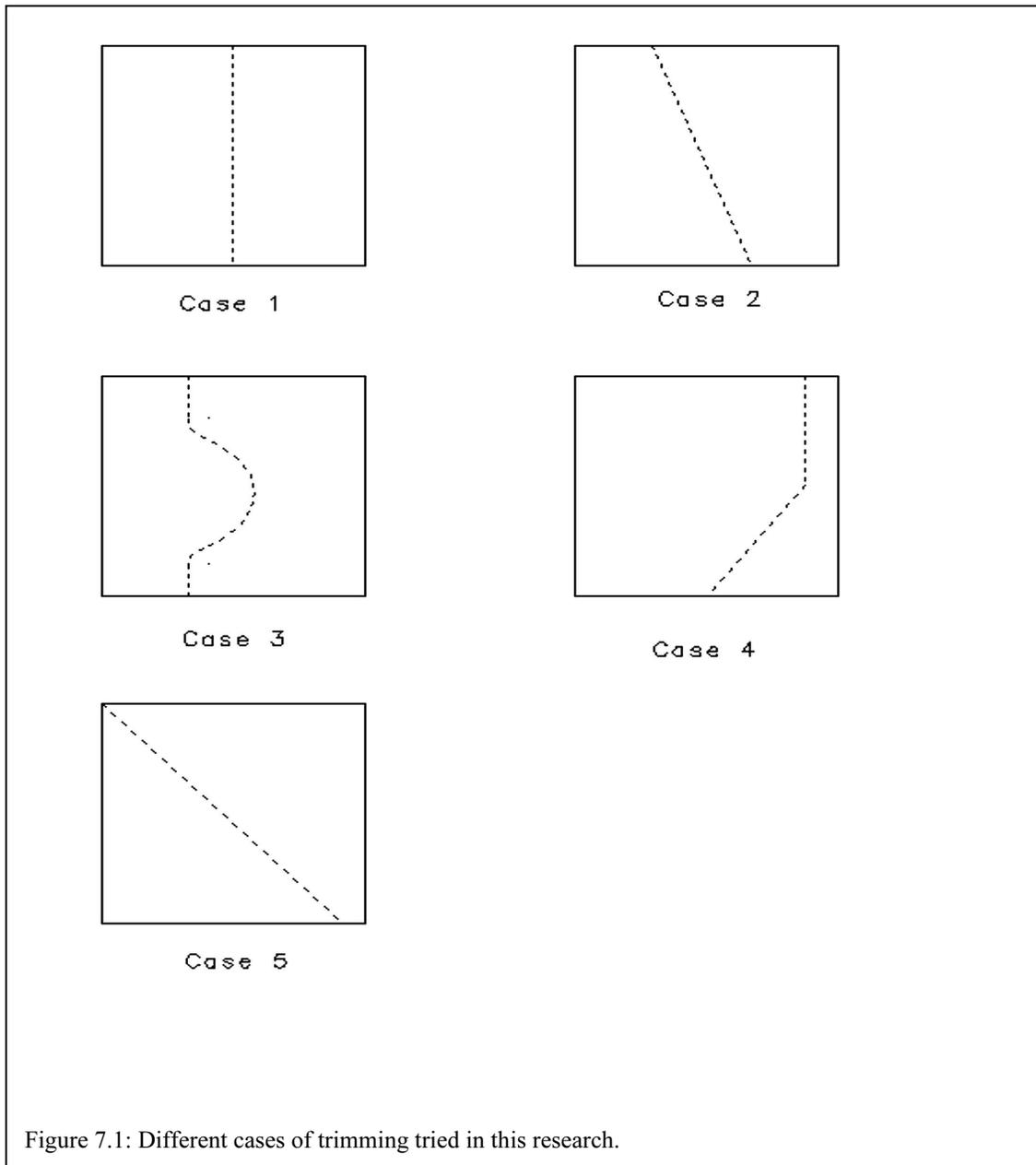


Figure 7.1: Different cases of trimming tried in this research.

Compilation Information:

```
!=====
! PROGRAM TITLE: shade_1
!
! MACHINES USED: IBM RISC 6000 with 256 MB RAM
!
! OPERATING SYSTEM: AIX 4.3.3
!
! C++ COMPILER: Version 4.0
!
! MATLAB: Version 5.2
!
! APPROXIMATE COMPUTATION TIME: 4-5 seconds
!
!=====
```

Trimming Case	% errors of optimized trim patches/ no of points used	% errors of unoptimized patches/ no of points used
Case 1:	0.022 / 8	0.022 / 21
Case 2:	0.040 / 16	0.040 / 21
Case 3:	0.055 / 13	0.022 / 21
Case 4:	0.070 / 17	0.035 / 21
Case 5:	0.080 / 18	0.070 / 21

Table 1: Table listing the % errors of the trimmed patches (optimized and non-optimized) with the original surface along with the number of points used to describe the trimmed patches for different trim cases.

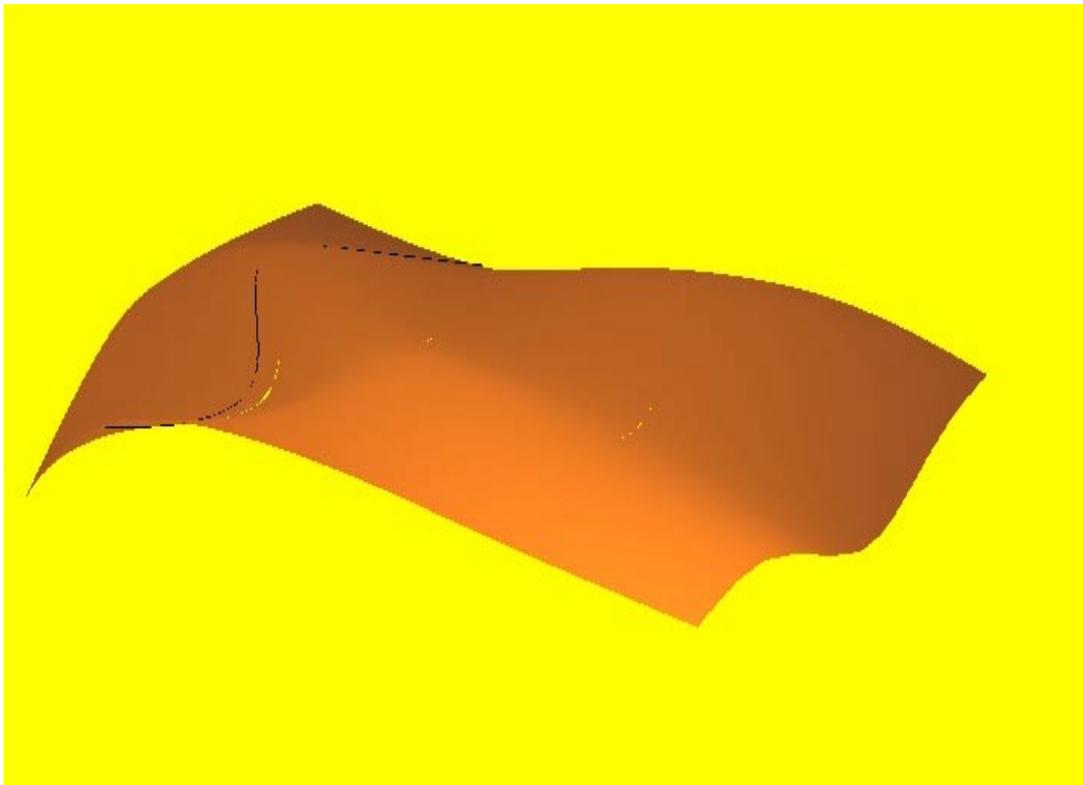


Figure 7.2: A snap shot of the surface with the unevenness in its topology highlighted.

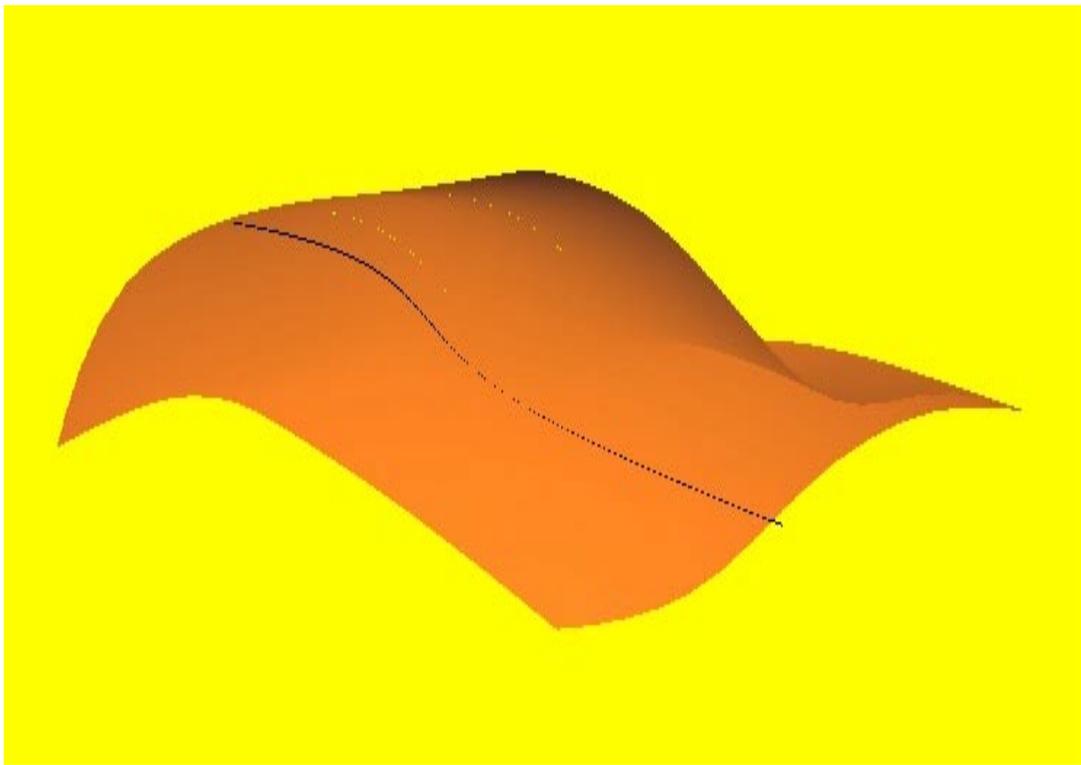


Figure 7.3: Another view of the surface showing the trimming curve for Case 1.

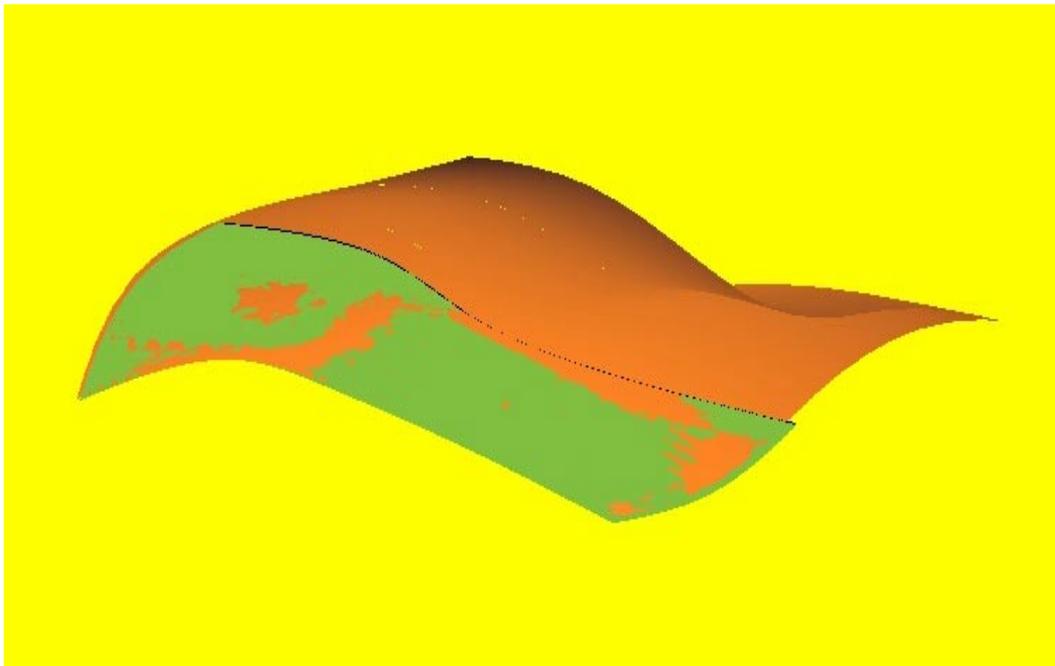


Figure 7.4: Image of the original surface overlapping the trimmed surface constructed with the optimized data point set for case 1. The data point set is optimized by surface interrogation.

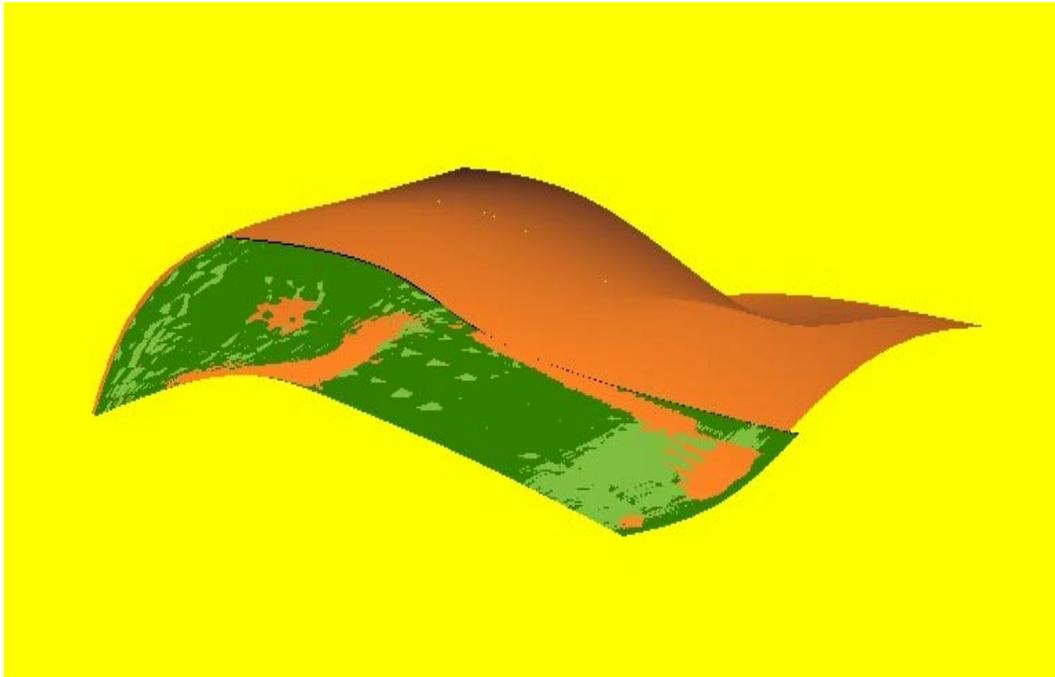


Figure 7.5: Image of the original surface overlapping both the trimmed surface constructed with the optimized data point set and the one constructed with the data point set obtained before surface interrogation for case 1.

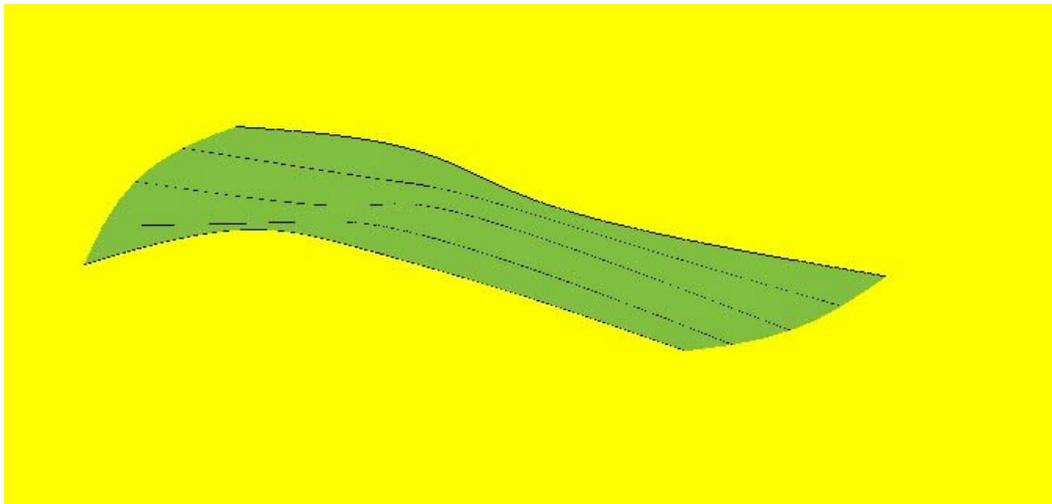


Figure 7.6: Rendered image of the optimized trimmed patch for case 1 of the trimming curve.

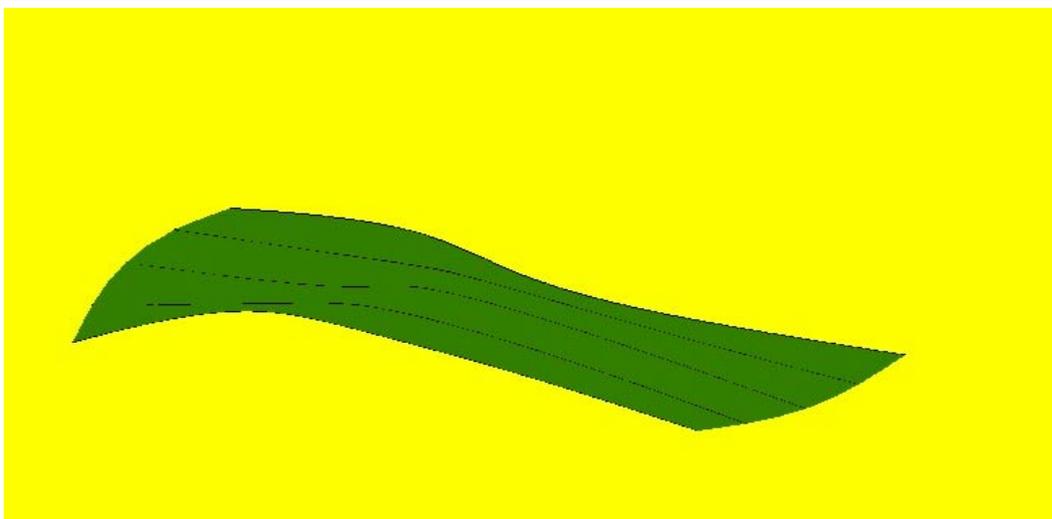


Figure 7.7: Rendered image of the trimmed patch before optimization. Optimization is achieved through surface interrogation for case 1 of the trimming curve.

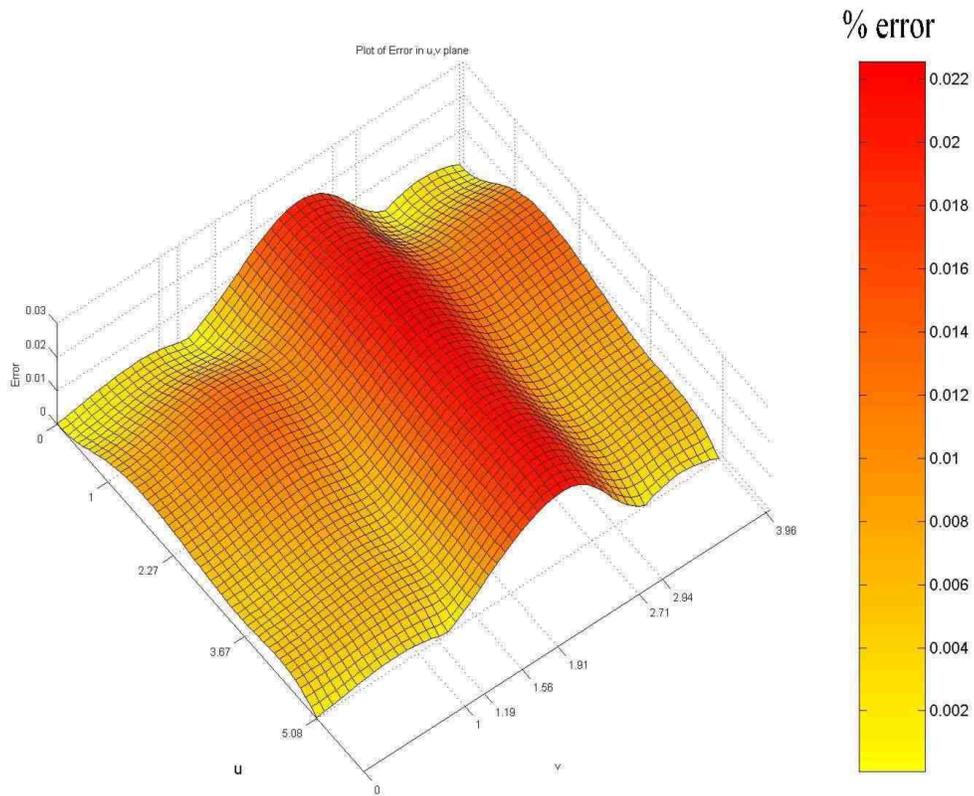


Figure 7.8: Positional error plot of the optimized trimmed patch for case 1 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of only 8 points.

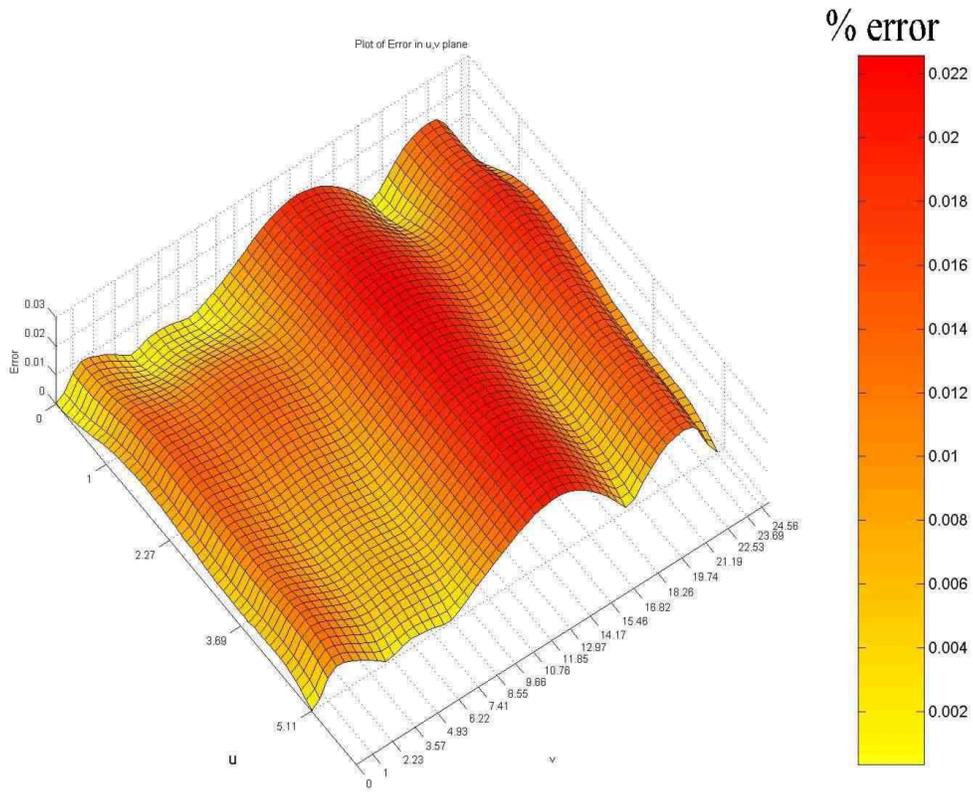


Figure 7.9: Positional error plot of the unoptimized trimmed patch for case 1 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made 21 points.

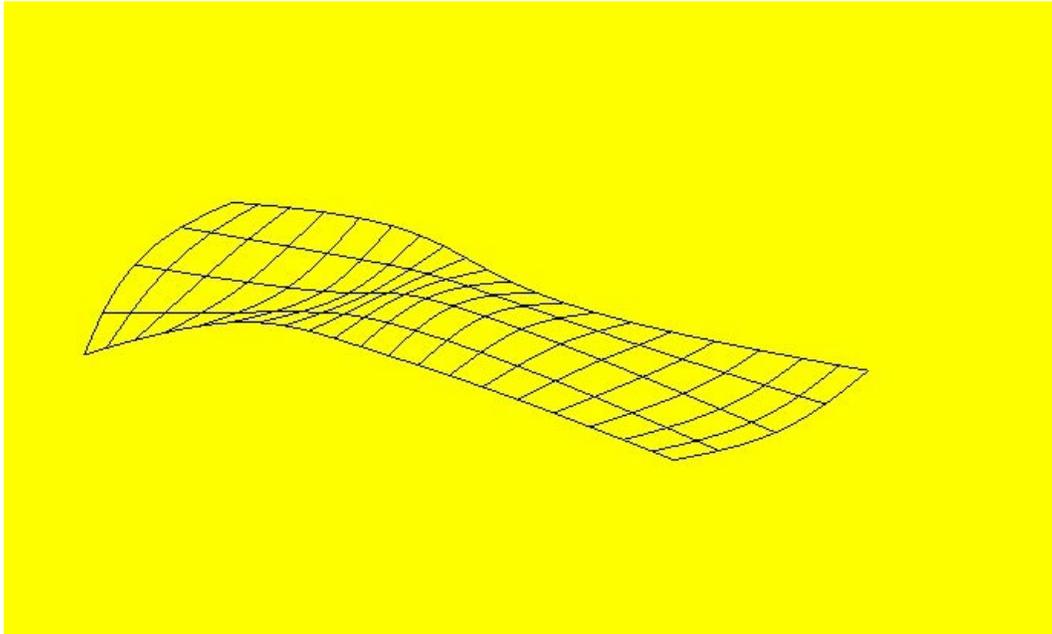


Figure 7.10: Screen shot showing the iso-parametric curves considered to aid in surface interrogation of the trimmed patch for case 1 of the trimming curve.

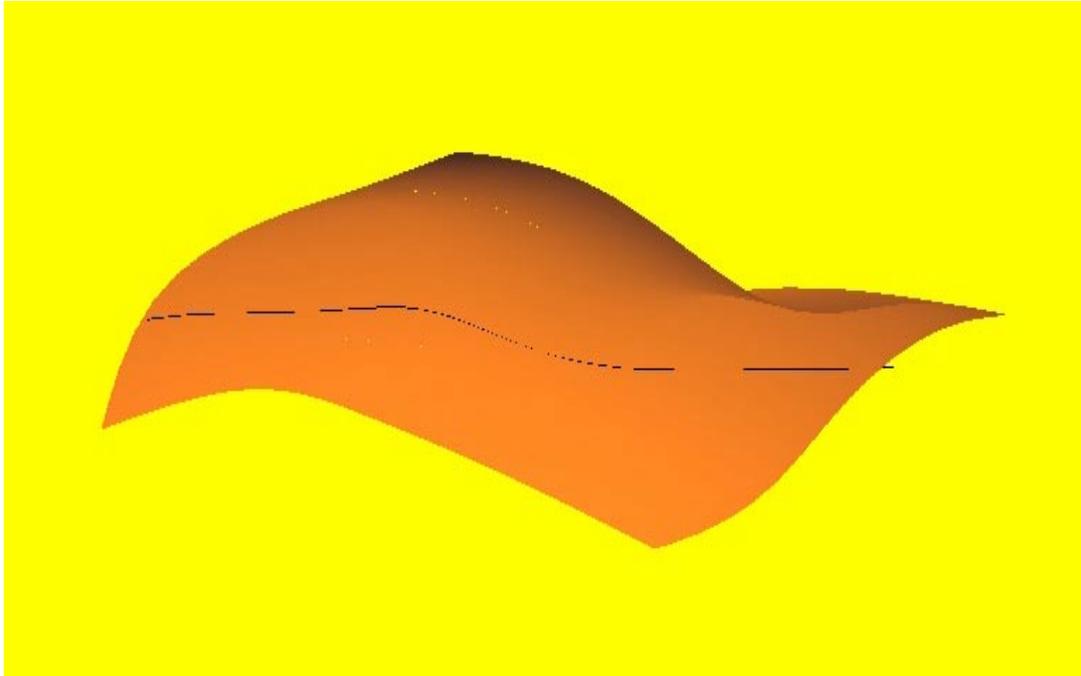


Figure 7.11: Rendered image of the surface showing the trimming curve for Case 2.

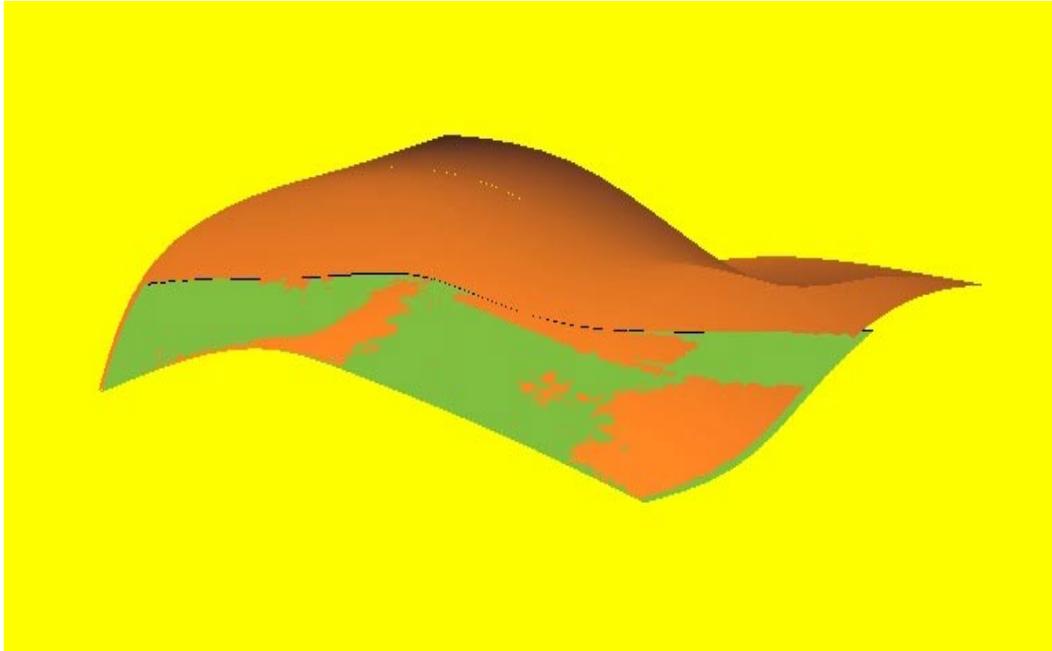


Figure 7.12: Image of the original surface overlapping the trimmed surface constructed with the optimized data point set for case 2. The data point set is optimized by surface interrogation.

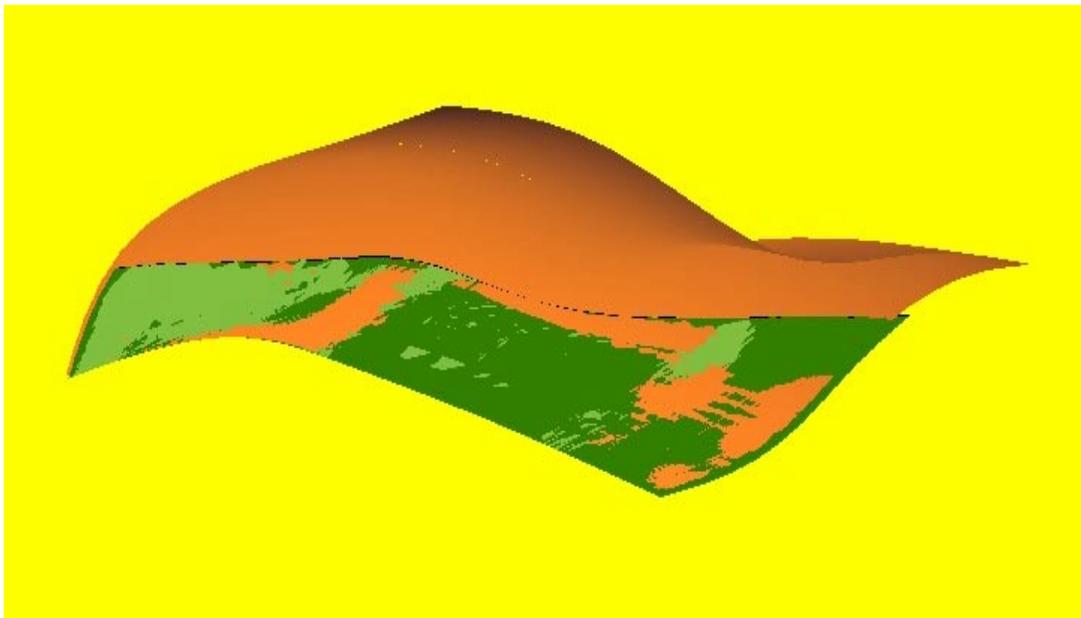


Figure 7.13: Image of the original surface overlapping both the trimmed surface constructed with the optimized data point set and the one constructed with the data point set obtained before surface interrogation for case 2.

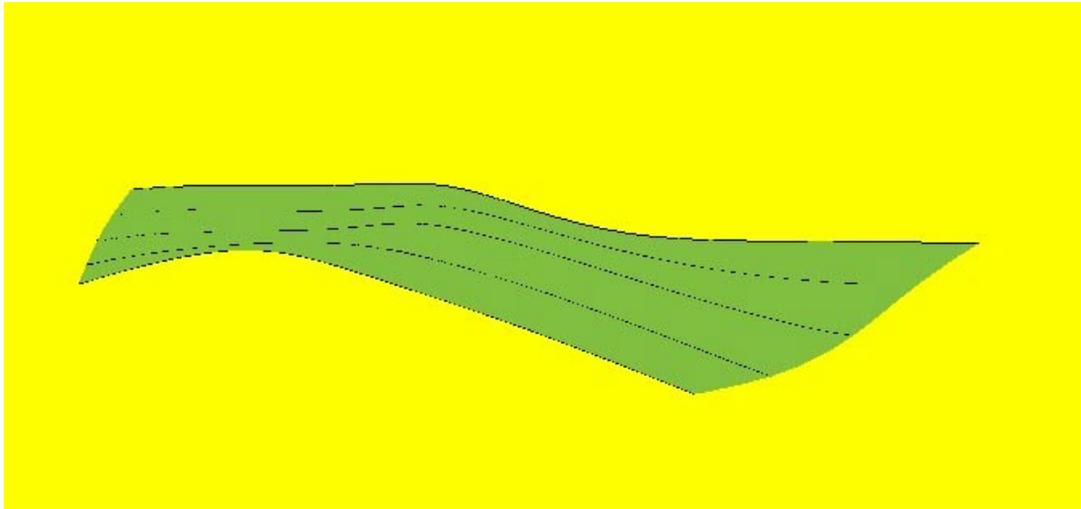


Figure 7.14: Rendered image of the optimized trimmed patch for case 2 of the trimming curve.

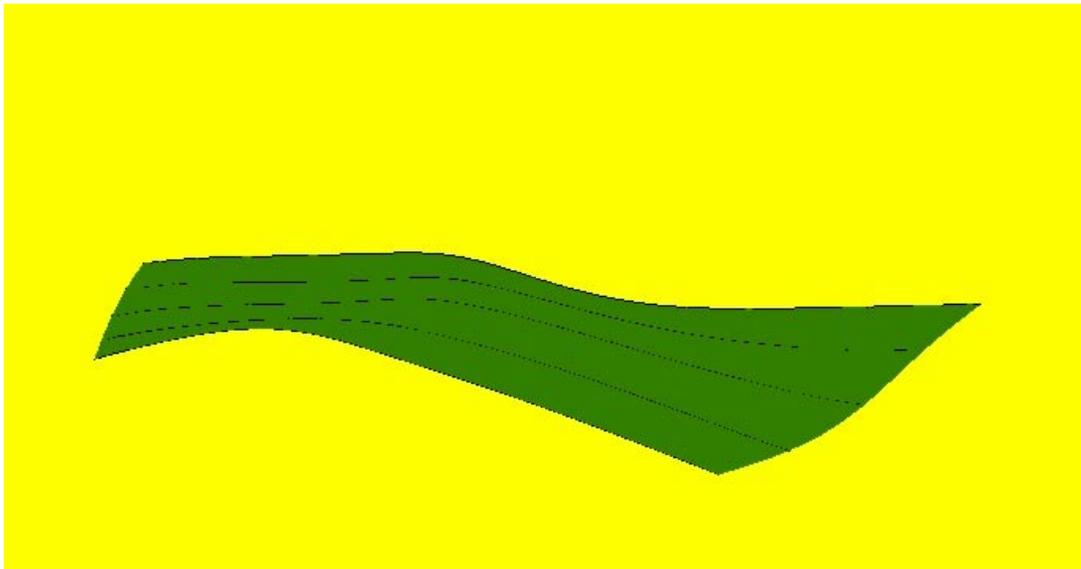


Figure 7.15: Rendered image of the trimmed patch before optimization. Optimization is achieved through surface interrogation for case 2 of the trimming curve.

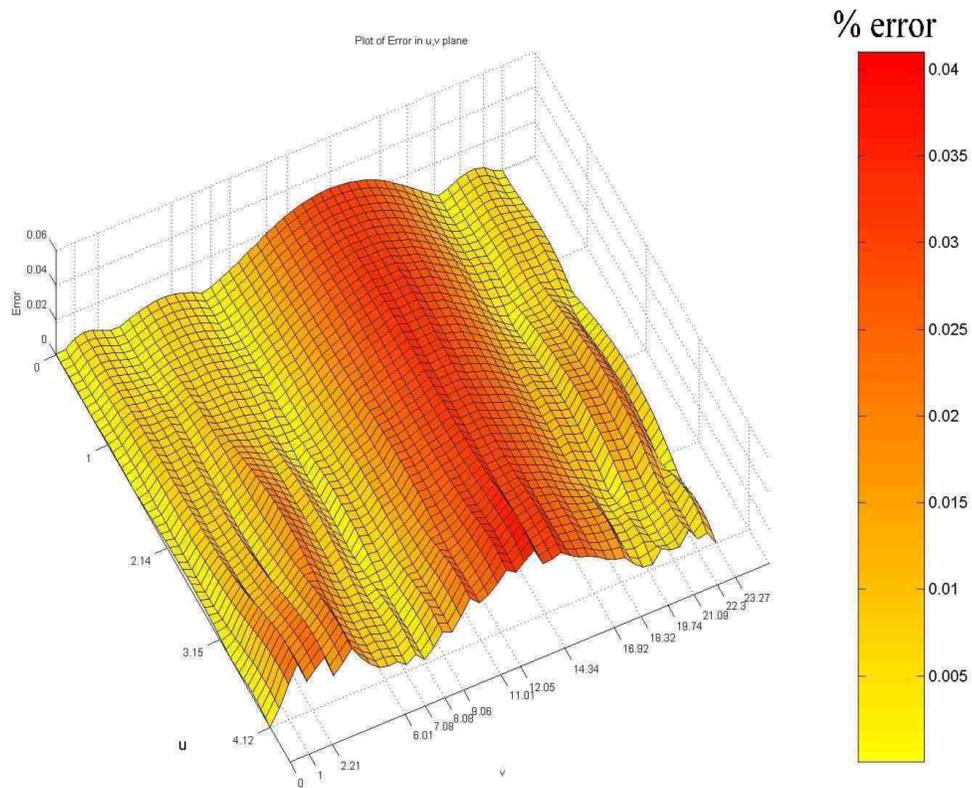


Figure 7.16: Positional error plot of the optimized trimmed patch for case 2 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of only 16 points.

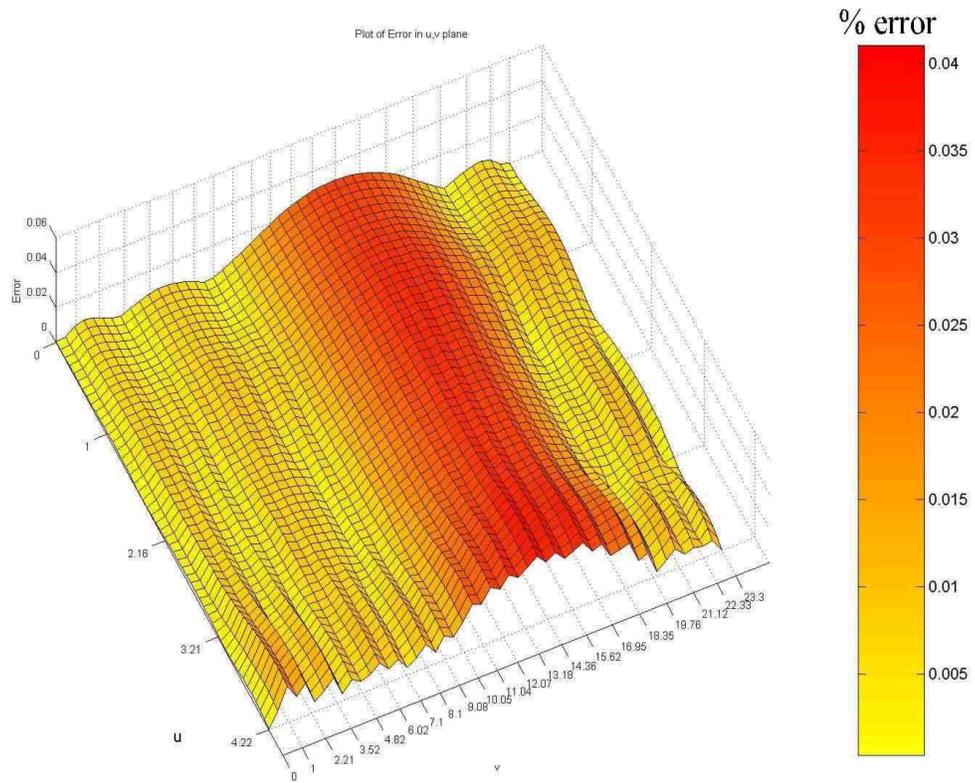


Figure 7.17: Positional error plot of the unoptimized trimmed patch for case 2 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of a constant 21 points irrespective of the case.

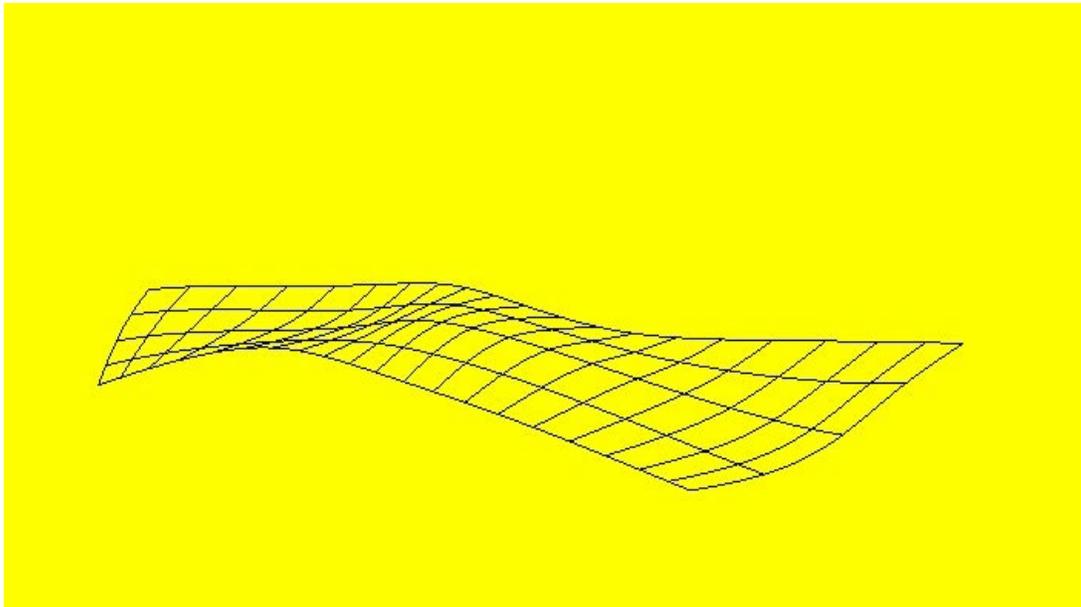


Figure 7.18: Screen shot showing the iso-parametric curves considered to aid in surface interrogation of the trimmed patch for case 2 of the trimming curve.

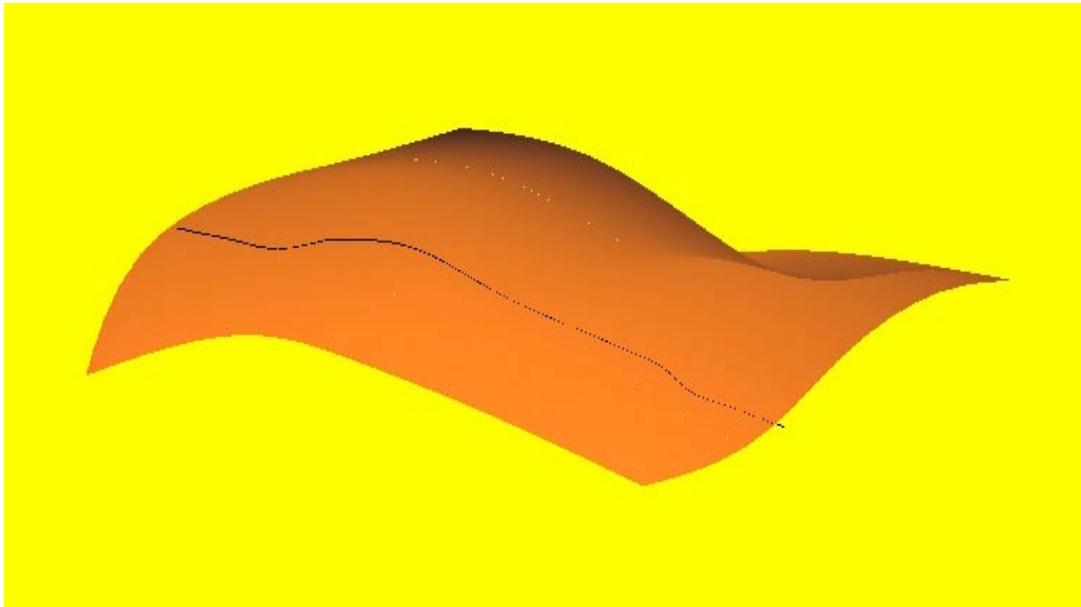


Figure 7.19: Rendered image of the surface showing the trimming curve for Case 3.

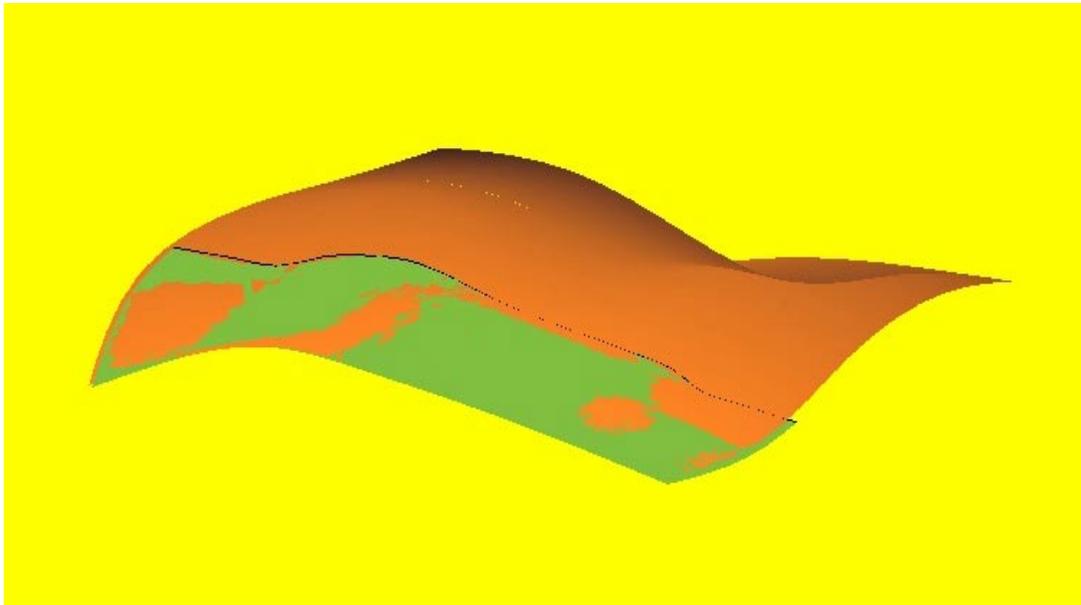


Figure 7.20: Image of the original surface overlapping the trimmed surface constructed with the optimized data point set for case 3. The data point set is optimized by surface interrogation.

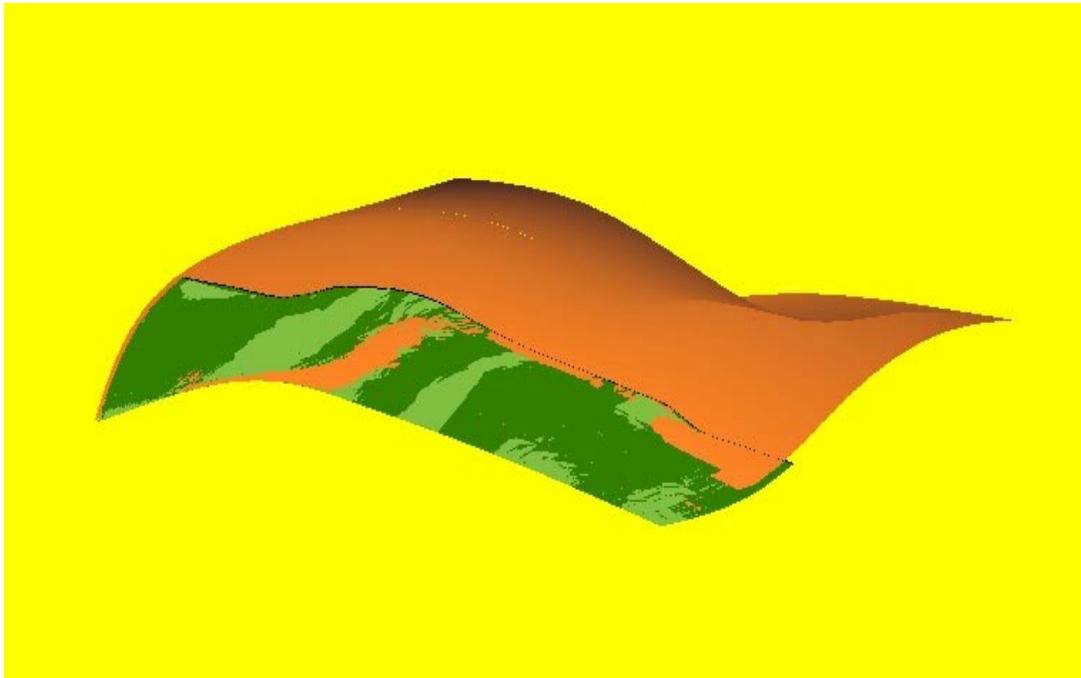


Figure 7.21: Image of the original surface overlapping both the trimmed surface constructed with the optimized data point set and the one constructed with the data point set obtained before surface interrogation for case 3.

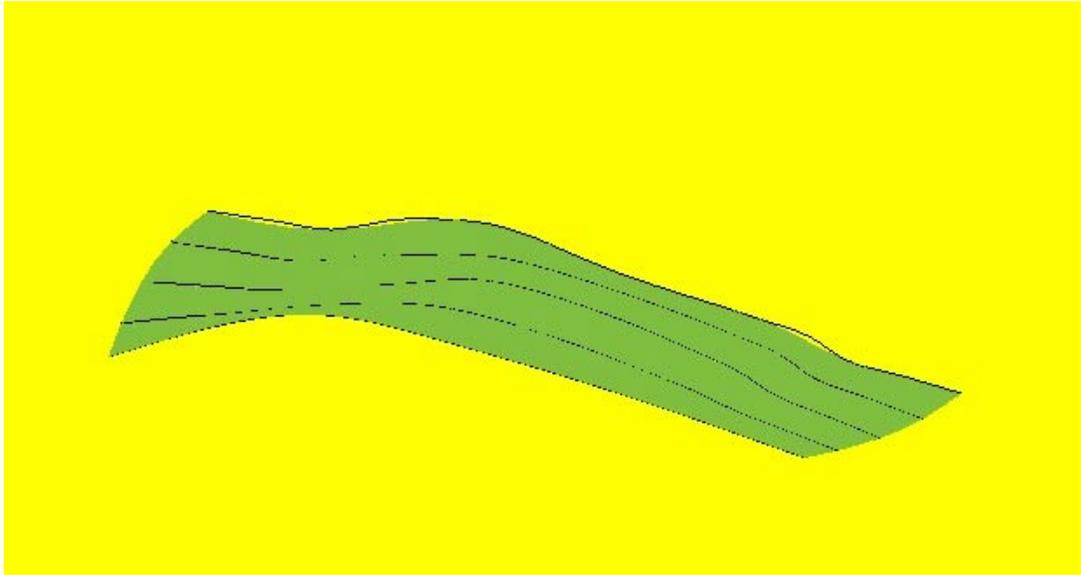


Figure 7.22: Rendered image of the optimized trimmed patch for case 3 of the trimming curve.

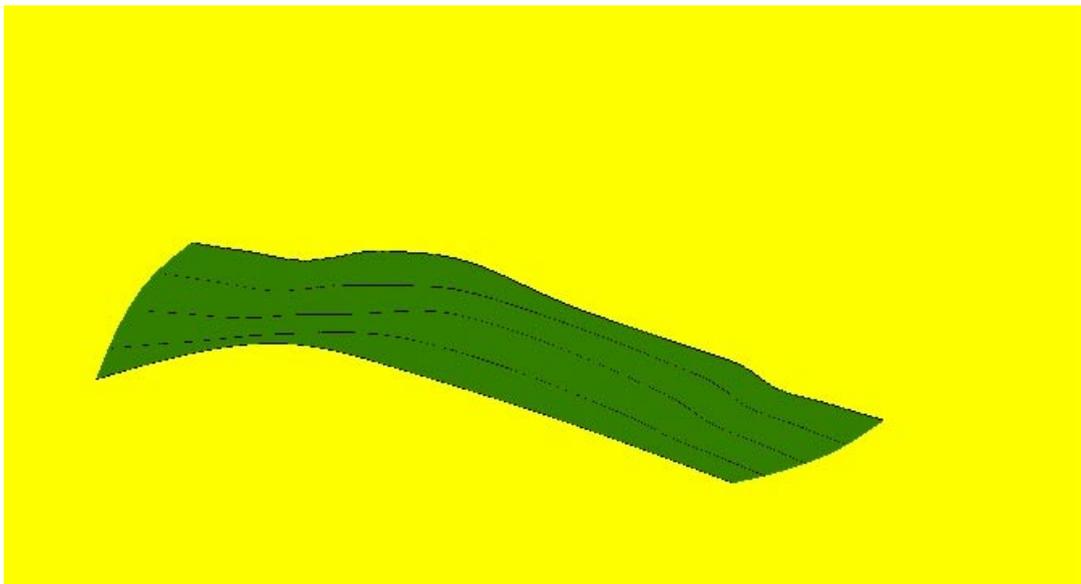


Figure 7.23: Rendered image of the trimmed patch before optimization. Optimization is achieved through surface interrogation for case 3 of the trimming curve.

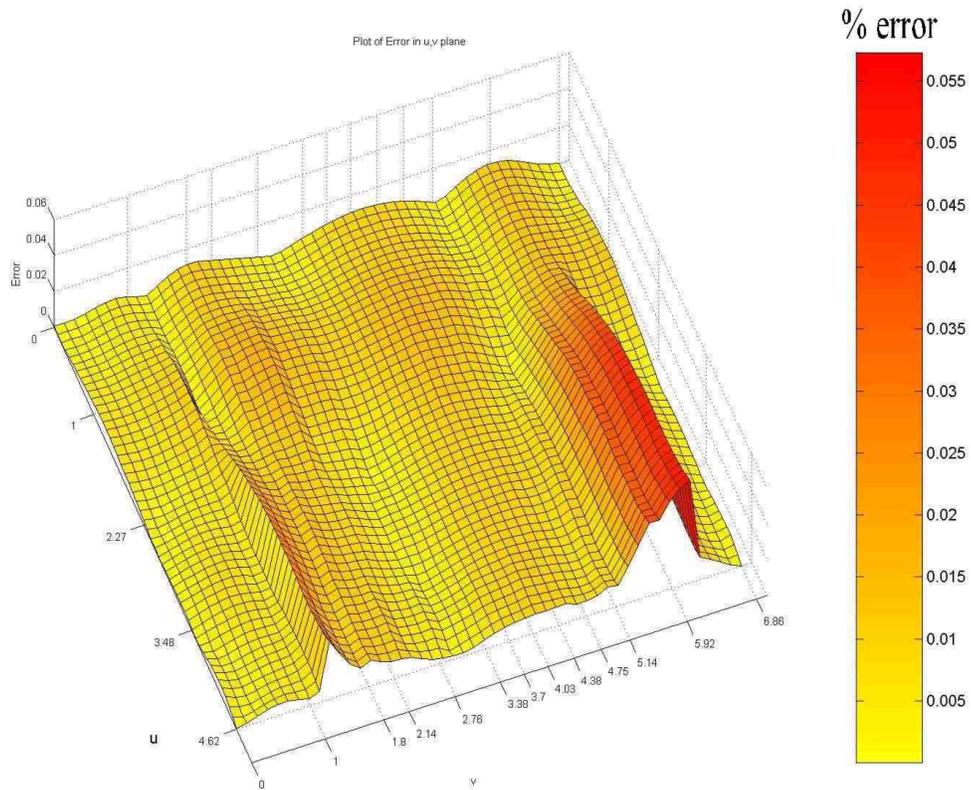


Figure 7.24: Positional error plot of the optimized trimmed patch for case 3 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of only 13 points.

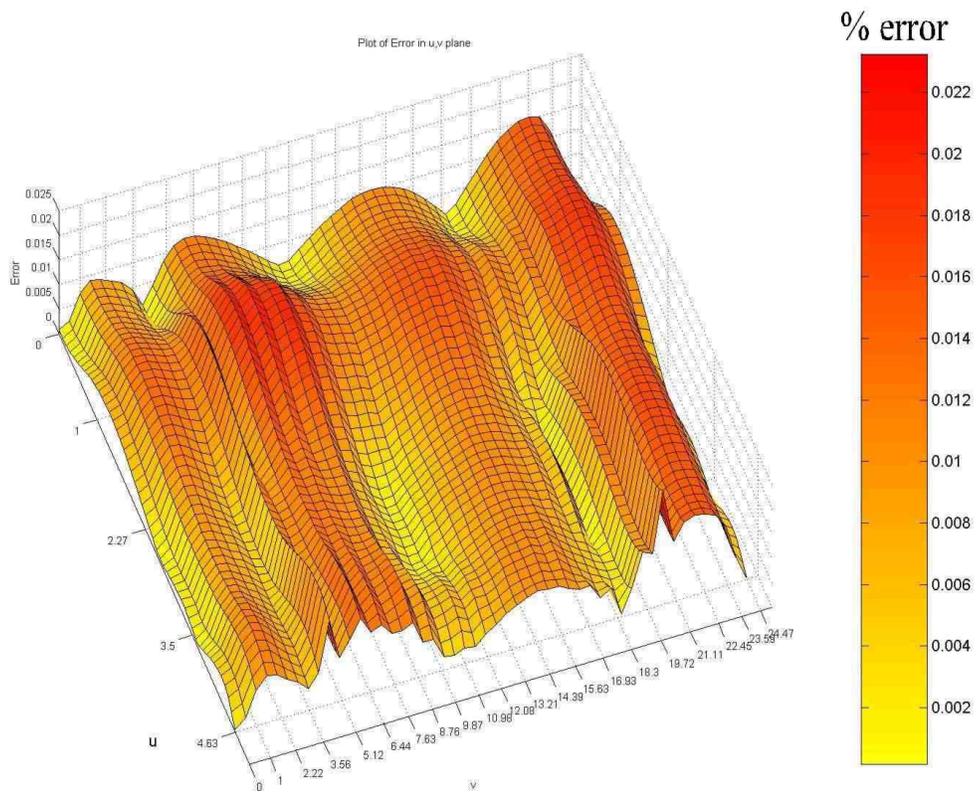


Figure 7.25: Positional error plot of the unoptimized trimmed patch for case 3 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of a constant 21 points irrespective of the case.

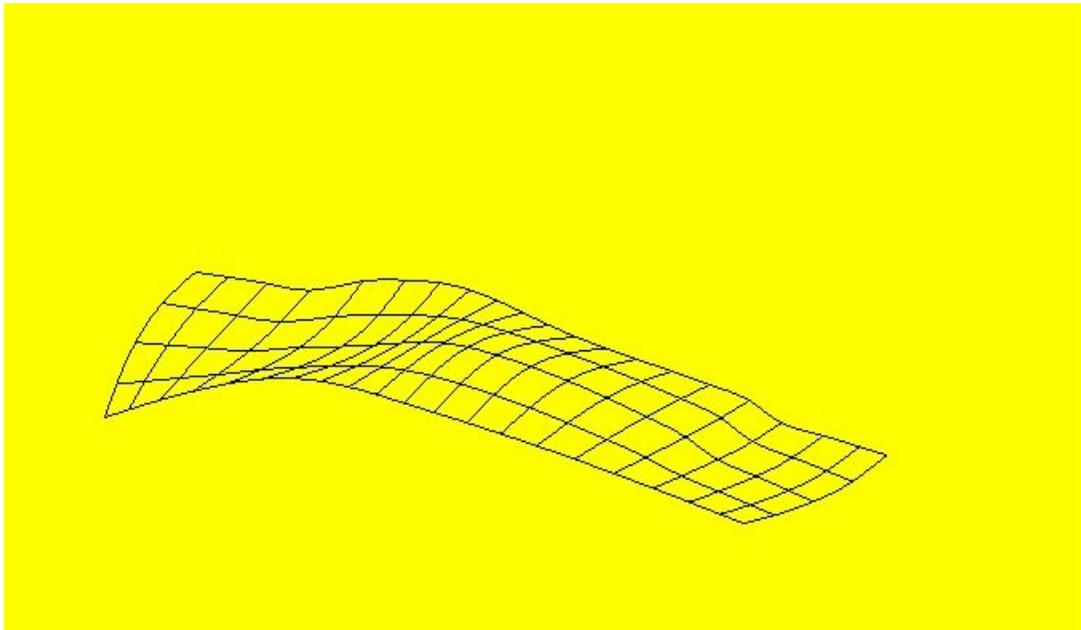


Figure 7.26: Screen shot showing the iso-parametric curves considered to aid in surface interrogation of the trimmed patch for case 3 of the trimming curve.

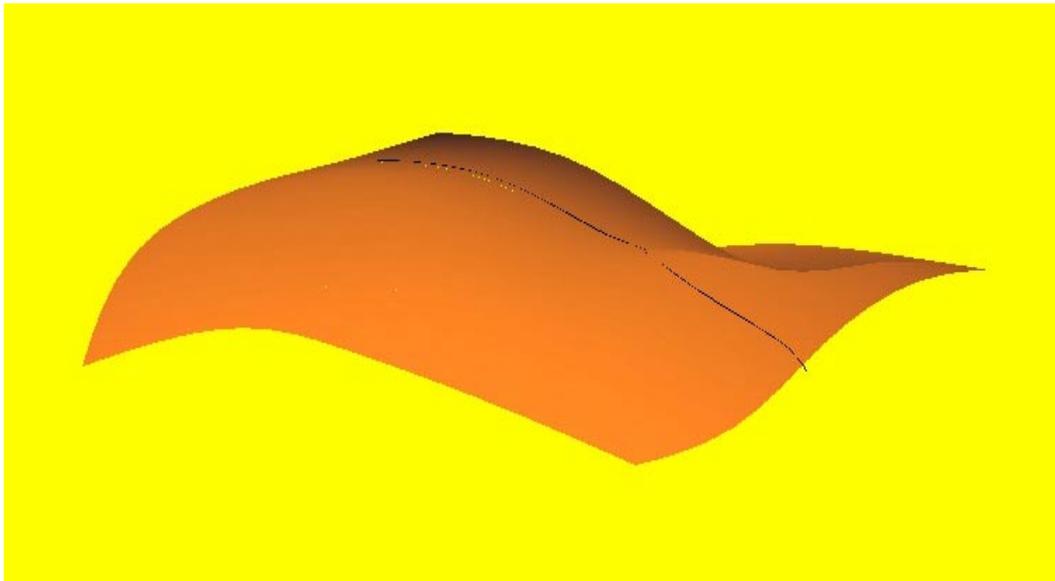


Figure 7.27: Rendered image of the surface showing the trimming curve for Case 4.

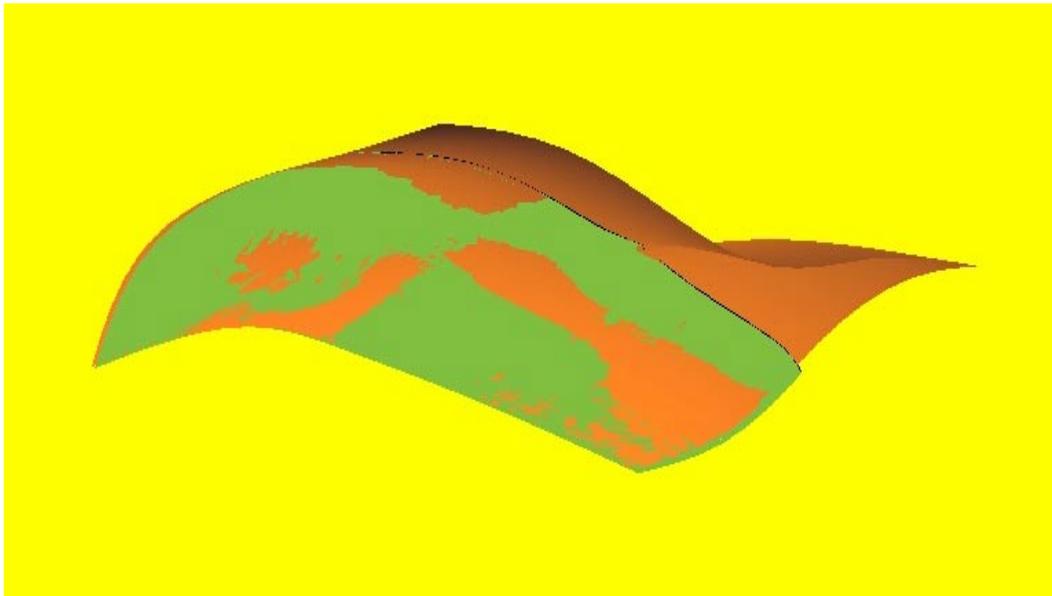


Figure 7.28: Image of the original surface overlapping the trimmed surface constructed with the optimized data point set for case 4. The data point set is optimized by surface interrogation.

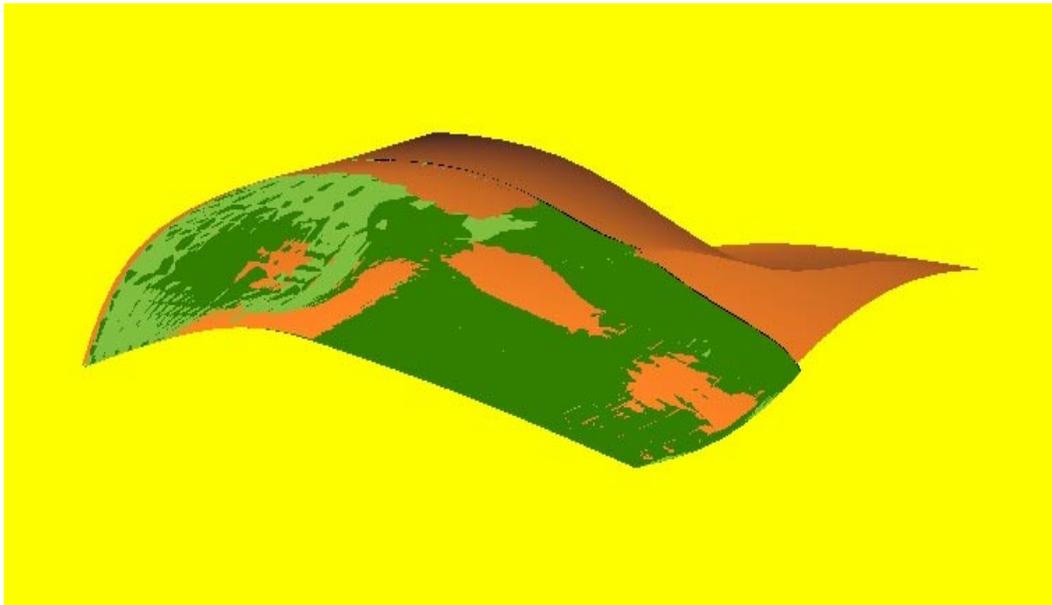


Figure 7.29: Image of the original surface overlapping both the trimmed surface constructed with the optimized data point set and the one constructed with the data point set obtained before surface interrogation for case 4.

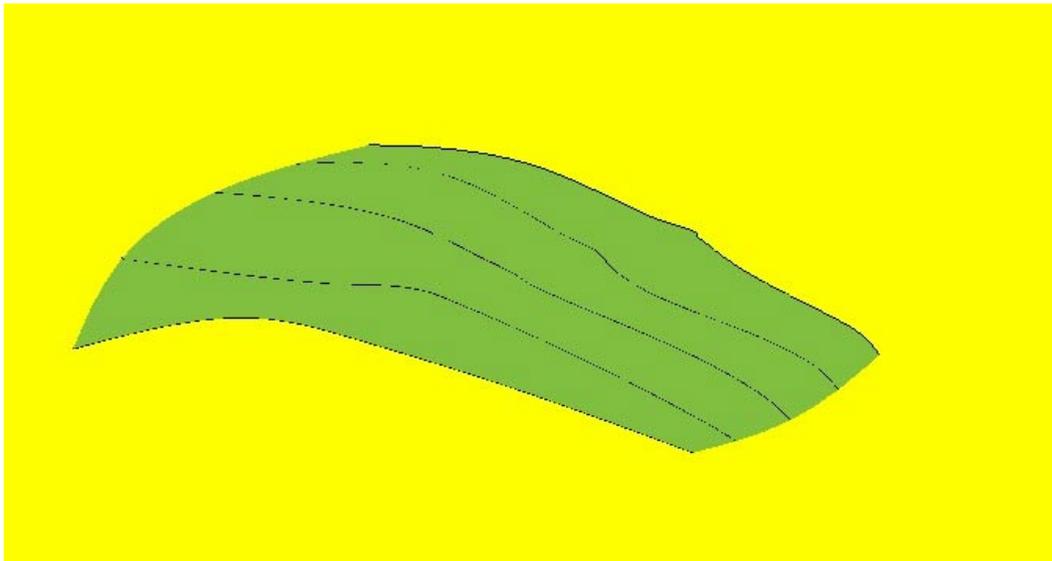


Figure 7.30: Rendered image of the optimized trimmed patch for case 4 of the trimming curve.

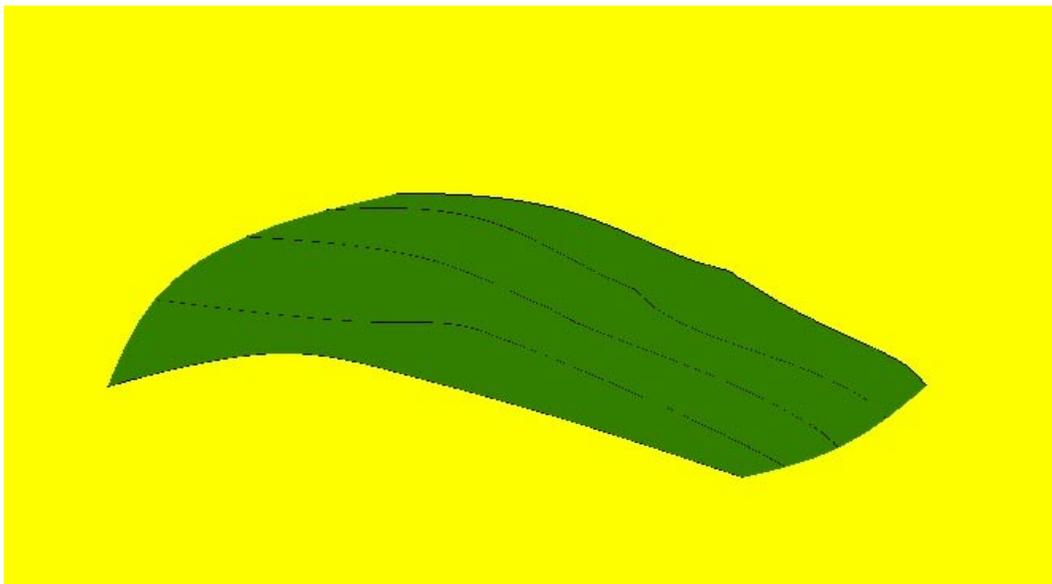


Figure 7.31: Rendered image of the trimmed patch before optimization. Optimization is achieved through surface interrogation for case 4 of the trimming curve.

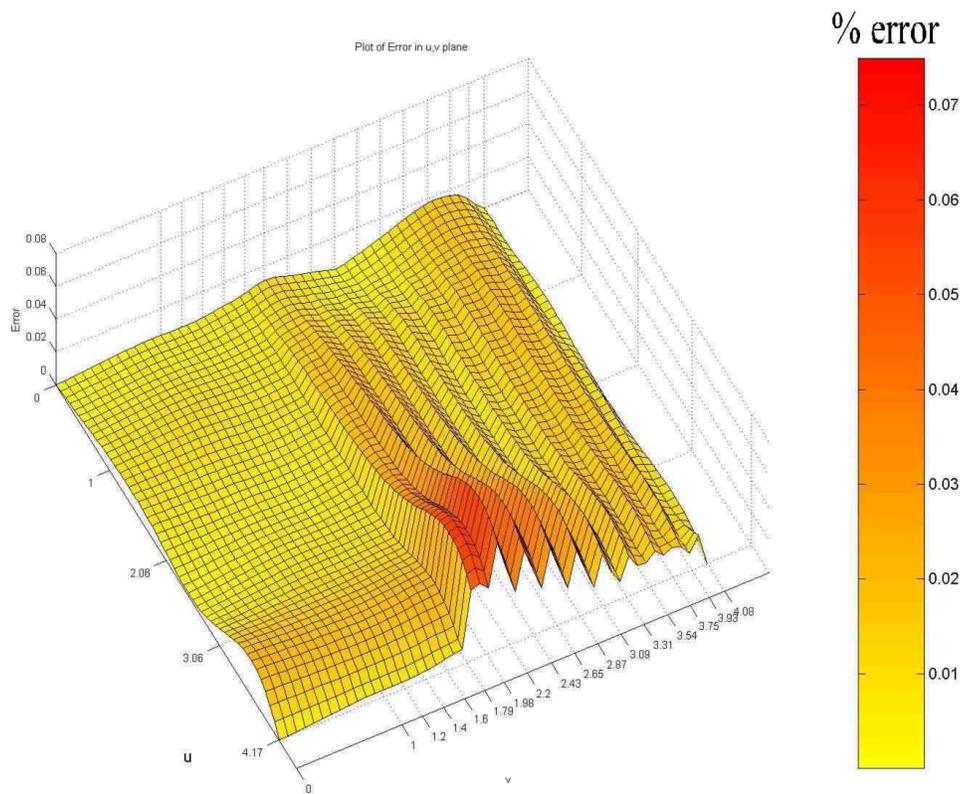


Figure 7.32: Positional error plot of the optimized trimmed patch for case 4 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of only 17 points.

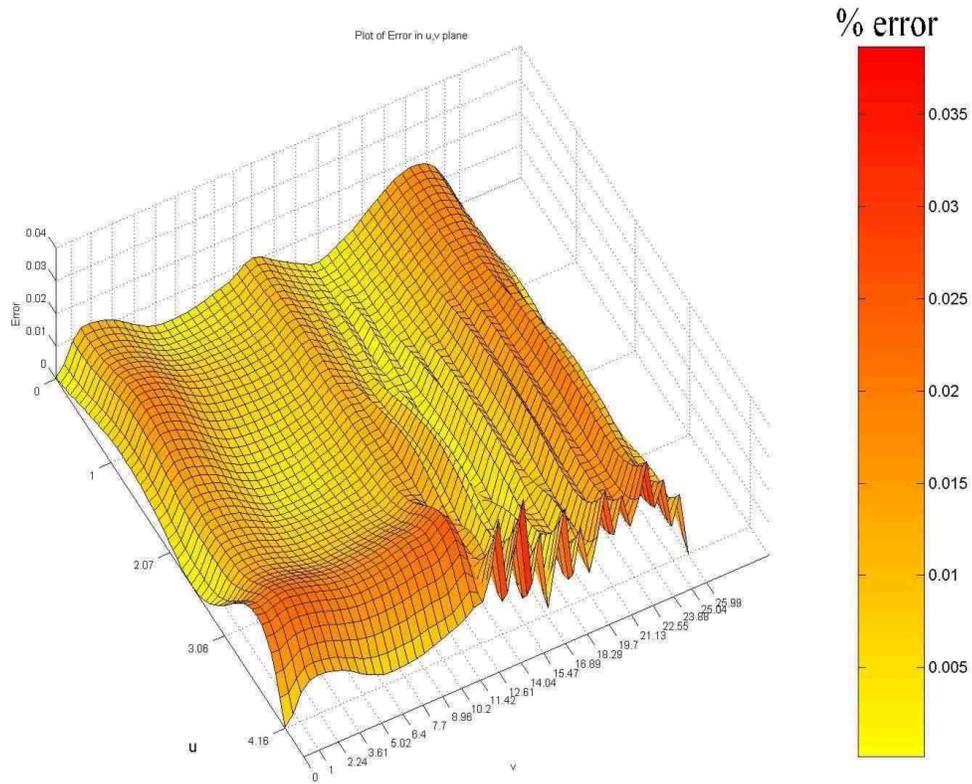


Figure 7.33: Positional error plot of the unoptimized trimmed patch for case 4 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made 21 points.

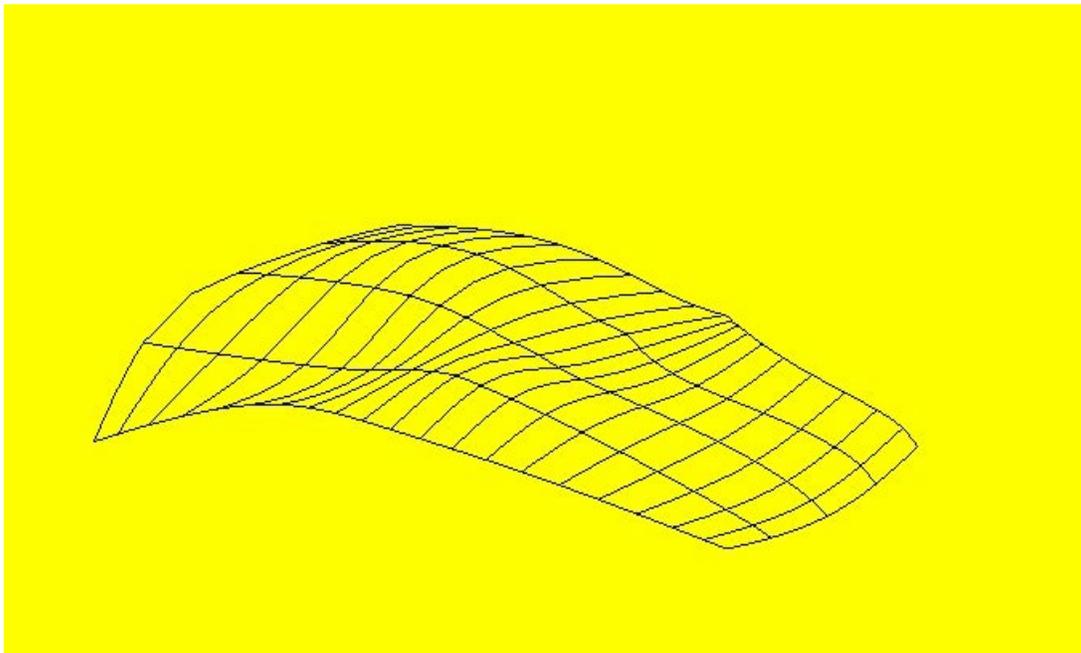


Figure 7.34: Screen shot showing the iso-parametric curves considered to aid in surface interrogation of the trimmed patch for case 4 of the trimming curve.

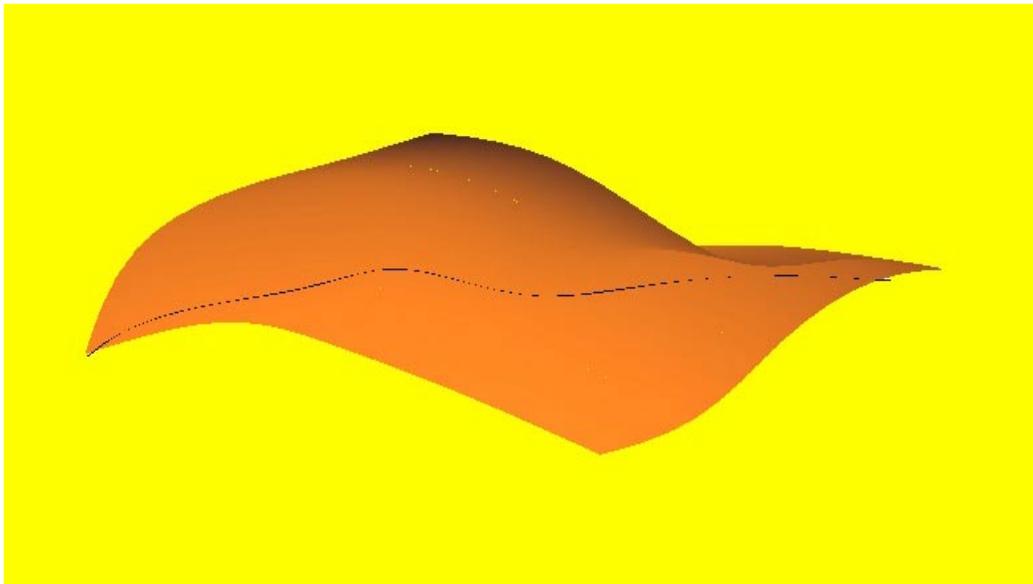


Figure 7.35: Rendered image of the surface showing the trimming curve for Case 5.

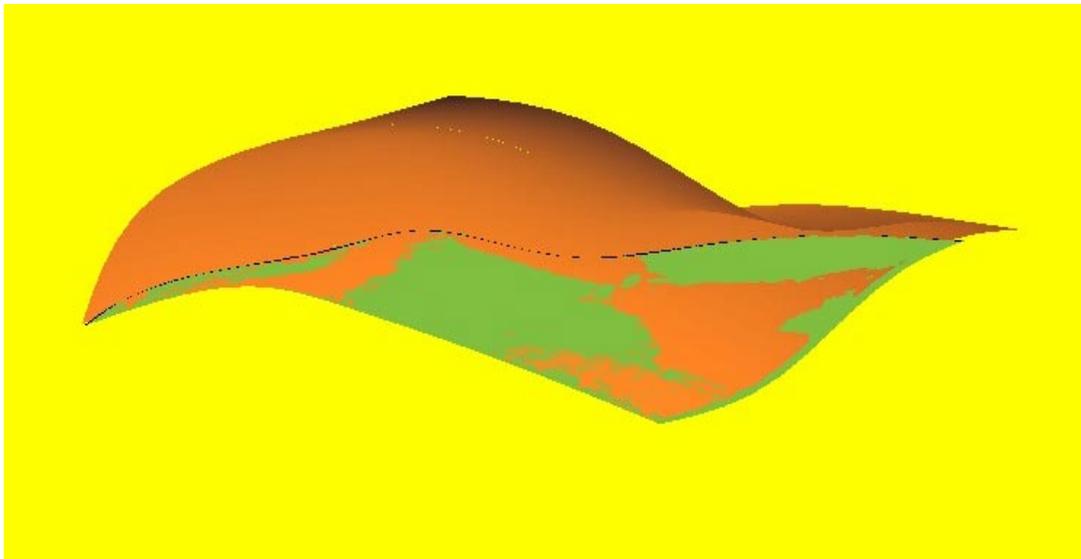


Figure 7.36: Image of the original surface overlapping the trimmed surface constructed with the optimized data point set for case 5. The data point set is optimized by surface interrogation.

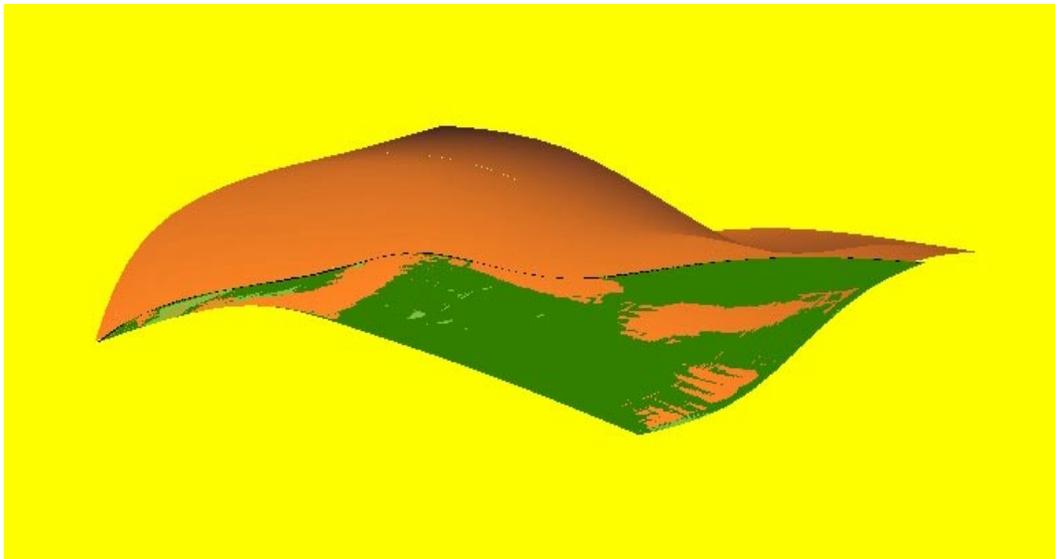


Figure 7.37: Image of the original surface overlapping both the trimmed surface constructed with the optimized data point set and the one constructed with the data point set obtained before surface interrogation for case 5.

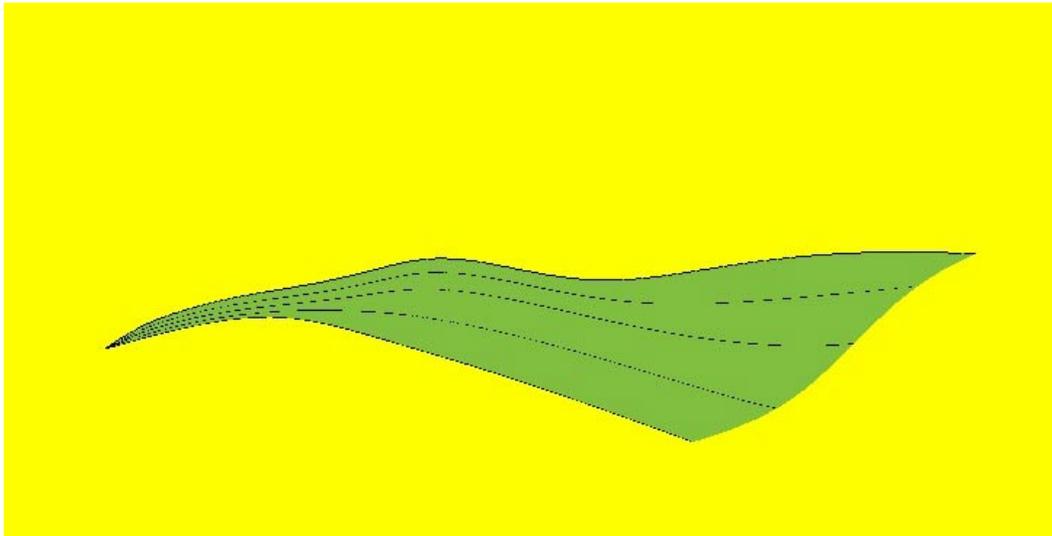


Figure 7.38: Rendered image of the optimized trimmed patch for case 5 of the trimming curve.

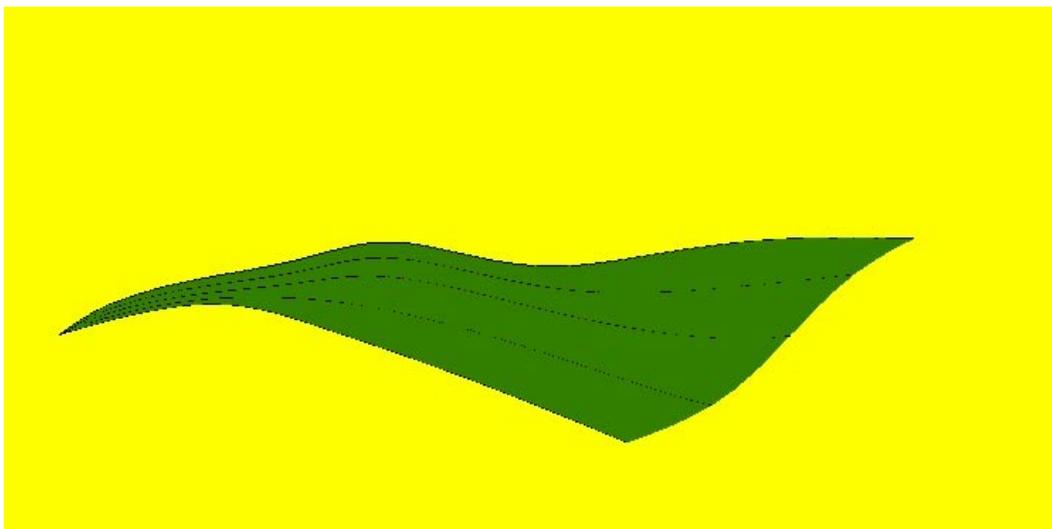


Figure 7.39: Rendered image of the trimmed patch before optimization. Optimization is achieved through surface interrogation for case 5 of the trimming curve.

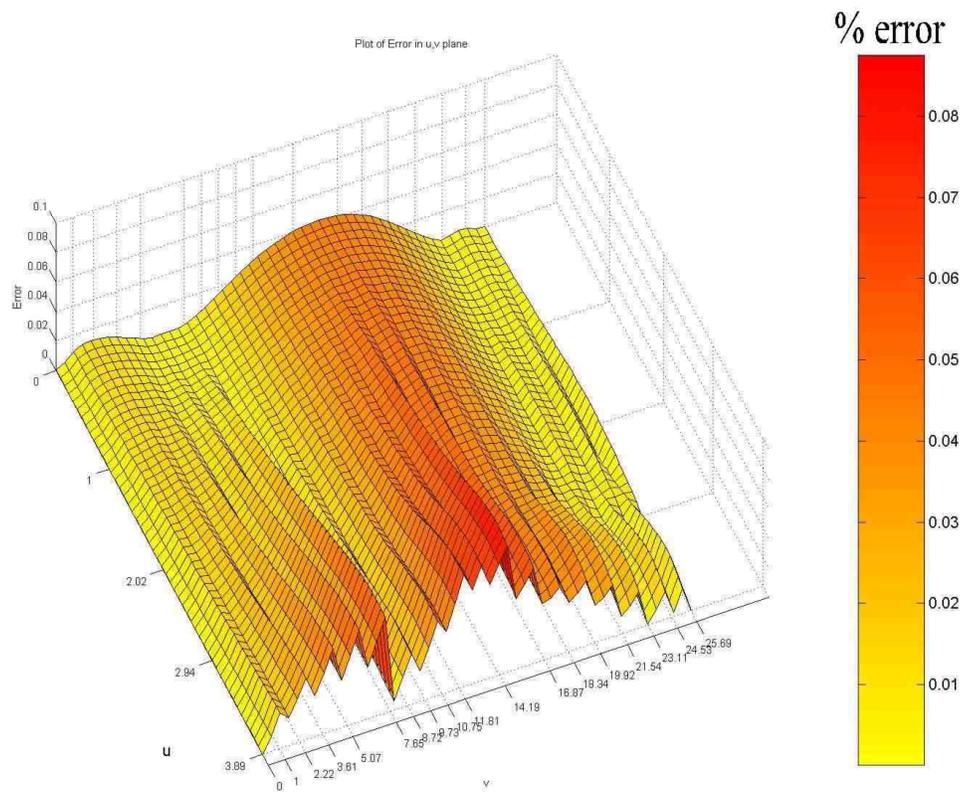


Figure 7.40: Positional error plot of the optimized trimmed patch for case 5 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of only 18 points.

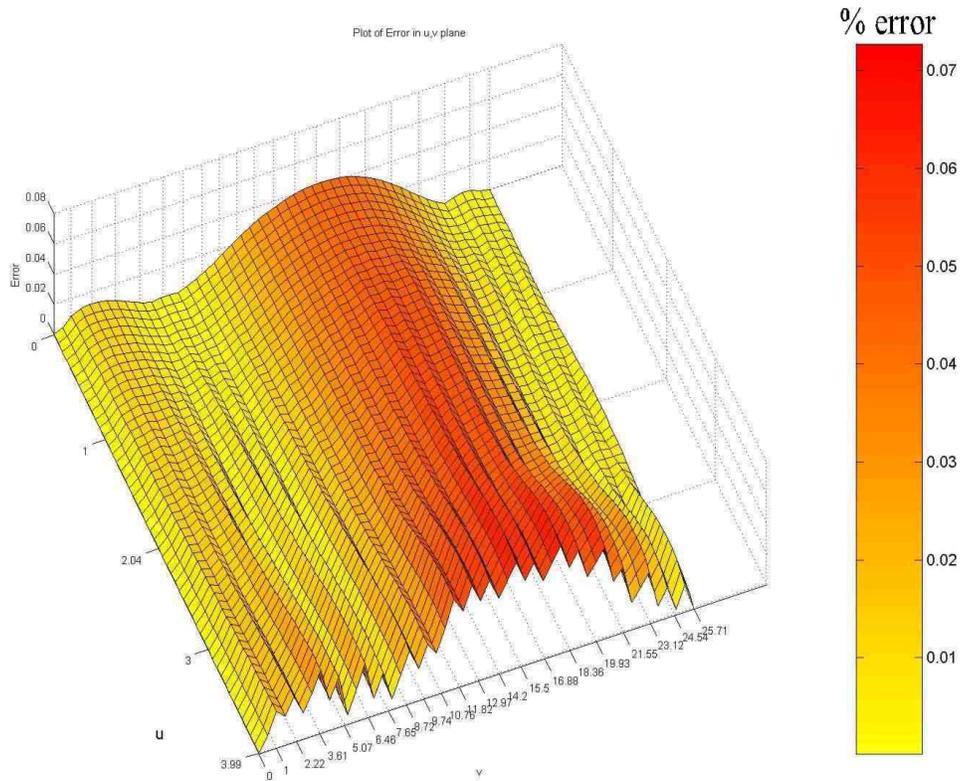


Figure 7.41: Positional error plot of the unoptimized trimmed patch for case 5 of the trimming curve. The bar on the right is a yardstick of the error value described as a percentage. Note that the trim curve described along the v direction in the parametric domain of the surface is made of 21 points.