

Genetic Algorithm in Removing Local NURBS Surface Irregularities Using Highlight Lines

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ABSTRACT

Highlight lines are well known surface smoothness evaluation tools. This paper explains a method with which the designer is enabled to smooth surfaces, by adjusting its highlight lines. The adjustment of highlight lines is performed by replacing the defective parts with replacement curves of designer's will. The modified control points of the surface, which produces the desired replacement curves, are determined using a genetic algorithm. The method's advantages are represented by using better replacement curves and an algorithm which, no matter how complex the replacement curve is, can find modified control points in the absence of algebraic relations.

ACM Categories and Subject Descriptors

J.6 [Computer Aided Engineering]:
Computer Aided Design(CAD).

General Terms

Design, Algorithms.

Keywords

Highlight Lines, NURBS surface, RCGA.

1. INTRODUCTION

Evenness and smoothness represent quality features of surfaces. Various methods have been developed for their evaluation, including visual display methods. These methods are also suitable for displaying the reflection status of the surface, so that viewers can determine surface quality in accordance with their own aesthetic demands. The highlight line method developed by K. P. Beier and Y. Chen in 1994 [1] also belongs to this category.

2. BACKGROUND

The surface correction method developed by C. Zhang and F. Cheng uses a simple replacement curve and describes the correlation between highlight lines and control points using a linear equation system by introducing many reductions [2]. As a consequence of the great number of reductions, the method yields adequate results only in a small range.

3. OBJECTIVE

Regarding the method described, the main problem is represented by the complex algebraic correlation between the adjusted highlight lines and the control points of the corresponding surface. The research aims to develop a method to bridge this problem. This is intended to be achieved by using a new tool, genetic algorithm, which – no matter how complex the replacement curves are – can find modified control points even in the absence of direct relations.

4. PRESENTATION OF THE METHOD

The surface areas examined are of $200 - 300 \text{ cm}^2$, surface defects are local, extending to various directions, taking up 2-5% of the total area. The average density of the control point grid is 2–2.5 control points/cm (Fig. 1).

First, the light sources are established, then the corresponding highlight points are determined, through which then an interpolation NURBS curve is fitted.

Next task – to be completed subjectively by the user – is to mark out and redesign the highlight line sections to be considered as defective (shown in black in the middle of Fig. 1).

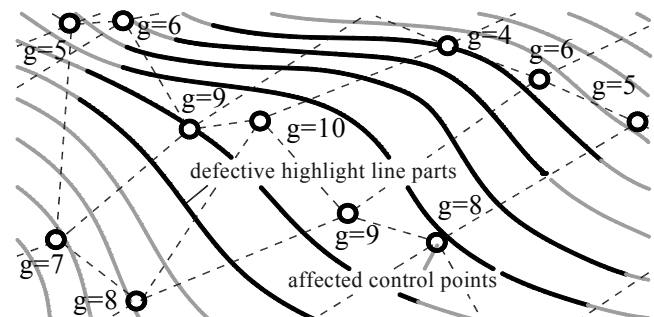


Figure 1. The selection frequency of certain control points on selected defective highlight line sections.

For each defective highlight line section, a number of surface points (G) in parametric space are determined. Aim of this, is to take into consideration the strength of influence of control points, on the examined highlight line sections. An influence constant (b) assigned then to the affected control points, in function of number g , which shows at how many surface points have been they affected (Fig. 1).

$$b = g \cdot 1 / G$$

Defective and redesigned highlight line sections are compared by using sample points too. For this purpose, points in geometric space are used, designated at identical lengths of arch (e.g. 1mm) along the line sections.

4.1 Structure of the Genetic Algorithm

Due to the continuous nature of the surface, the genetic algorithm applied is of real coding (RCGA). The search area and gene representation are individual, the operators applied are versions of those to be found in the literature [3], adjusted to this special task. They were applied by a software with VBA source code of own development, connected to Rhinoceros 4.0 NURBS modeler.

4.1.1 Search, and gene representation

The method searches for solutions by changing the position of affected control points. The size of the search space is the section of space defined by distance $t \cdot b$, normal to surface at affected control points. The value of t is to be determined by experience. The genes consist of control points, and the constant b assigned to them as an attribute of influence.

4.1.2 Generation of initial population

The algorithm was studied at a constant population of size 200. Initial variance is produced by the random modification of control point coordinates, which is identical for each coordinate direction:

$$\Delta P(x, y, z) = \pm \text{rnd} \cdot (t \cdot b)$$

4.1.3 Fitness function

The basis of fitness is the distance between the designed and the current highlight line. Partial functions valid by highlight line consist of the following:

$$f_{1j} = \sum_{i=1}^m (Q_i - A_i)^2, \quad f_{2j} = \sum_{i=1}^m a_i.$$

Where A_i is the current geometric point and Q_i is the geometric point on the designed line, m is the number of sample points. The second function examines whether the highlight line is close to the designed curve everywhere:

$$a_i = 0 \text{ if } d_i \leq \frac{1}{m} \sum_{i=1}^m |d_i - \bar{d}| + \bar{d} \quad a_i = d - \bar{d} \text{ otherwise.}$$

Where $d = Q_i - A_i$.

The fitness function valid for the examined part of surface:

$$F = \sum_{j=1}^l \frac{100}{1 + f_{1j} + f_{2j}}$$

Where l is the number of highlight lines.

4.1.4 Recombination

Recombination is performed on the coordinates x , y and z of control points. It is of the arithmetic type, BLX-alpha [3]. The use of the value $\alpha = 0.2$ yielded the best results. Similarly good results are yielded by single point 2D crossover [3] as well.

4.1.5 Mutation

As regards mutations, the best results were yielded by the non-uniform method [3], gradually decreasing the value of mutation with the progress of search. The mutation ratio applied is 0.12.

5. USABILITY TEST

The figures below show the proceeding of algorithm on an example of a car hood. On Fig. 3a, the initial state is shown. As the result of relatively high t value ($t=1.5$) in the beginning of search the average surface fitness is extremely low, as seen on Fig. 3b and Fig. 2.

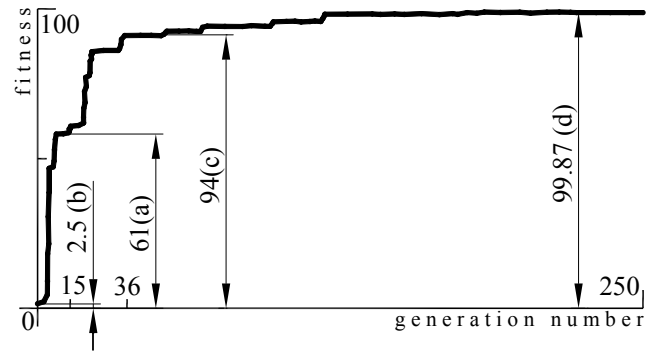


Figure 2. Runoff of the genetic search (Letters in brackets refer to Figure 3.).

The initial fitness was regained only after 15 generation, after which the fitness continued to increase rapidly, until it nearly stalled after 36 generation (Fig. 2). On Fig. 3d is shown the best surface reached after 220 generation.

The usability test performed was successful, the method was capable to find the surface corresponding to designed highlight lines.

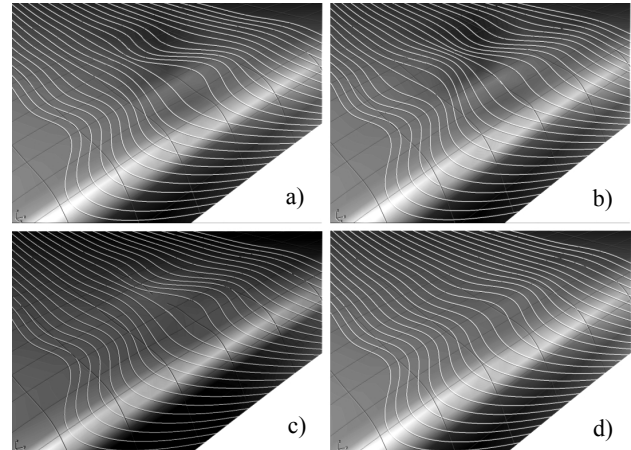


Figure 3. Highlight lines in different stages of search.

6. REFERENCES

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