Thesises

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In this Ph.D. work new theoretical and practical results were achieved concerning the reverse engineering of complex free-from shapes.

Thesis 1: Segmentation

I worked out a new segmenting paradigm called functional decomposition (see Dissertation, Chapter 3).

- Instead of boundary curve based techniques I proposed to identify relatively large, numerically stable *point regions*. In this way, it is easy to safely segment the point cloud and generate the related surfaces based on reliable interior data points. It is not necessary to fix the boundary curves, which turned out to be an error-prone process.

- The result of my analysis was, that a certain amount of user assistance is necessary for segmenting free-form shapes. In this context I suggested to apply an abstract model in which surfaces are classified as *primary surfaces* or *feature surfaces*, and there is a well-defined *hierarchy* between these elements. Surfaces at the lower levels are always dependent on the higher level elements. Dependencies are realised by special mathematical constraints such as smoothness between the adjacent surface elements.

- An important idea in this paradigm is to provide a tool to exclude points which belong to another surfaces. The surface generation must be capable of handling these so-called *ignore-areas* and holes where there is no available data. The resulting surfaces should naturally bridge the missing portions and provide an overall fair shape.

- I proposed to *compute and locate* the final boundary curves in an automatic way. The process starts form the rough segmentation curves and it uses the previously reconstructed higher level surfaces and their natural extensions.

Thesis 2: Advanced surface fitting

Advanced surface fitting includes the following results (see Dissertation, Chapter 4).

- I elaborated a new method which generates a suitable *reference surface* on which data points can be projected without fold-overs. This surface is used to generate a good, B-spline-like initial parametrisation.

- I developed a method to automatically control the *surface smoothness* during the fitting process, which terminates when the final approximation tolerance is reached.

- In regions where there are relatively few data points compared to the available number of control points, the least-squares approximation may extremely oscillate. I recognised, that these so-called *weakly defined control points* cannot be sufficiently controlled by *global smoothness functionals* and introduced a special algorithm to localise and constrain them.

- I developed a new algorithm for *inserting knots* based on the geometry of the surfaces and the so-called orthogonal deviation of the data points. It is capable to locate those knot intervals, where the additional degrees of freedom are needed the most to improve the approximation.

Thesis 3: Reconstructing swept feature surfaces
Results concerning the reconstruction of a special class of surfaces can be found in Chapter 5 of the dissertation.

- I developed a model of *swept surfaces with slowly varying profile* which I identified as an important feature class and a useful engineering abstraction.

- I proposed to apply the *rotation minimising frame* as the reference frame within the above model. I worked out a special tracing algorithm, which determines the spine curve of the feature surface.

- I elaborated a *constrained surface fitting* technique to reduce the geometrical freedom by constraining the feature boundaries to lie on the primary surfaces and enforce the control points in the normal planes of the spine curve.

- I developed an algorithm to *relocate feature boundaries* on the primary surfaces by minimising the bending energy of connecting curves in the sweeping planes.

Thesis 4: Curves on surfaces
Chapter 6 of the dissertation describes the problems of representing and computing a parametric curve on a tensor product B-spline surface. The main results are the following:

- I analysed previous approaches for computing an *exact curve* on a surface and developed an efficient *blossoming scheme* for computing the control points of an exact curve on a surface.

- After investigating the problems of high degree exact solutions, I developed a new *degree reduction algorithm for B-spline curves*, which ensures tolerance driven approximation along the whole curve.

- I developed an alternative approach for approximating a curve on a surface based on an *extended curve fitting* algorithm, which incorporates properties of the differential geometry of the surface, as well.