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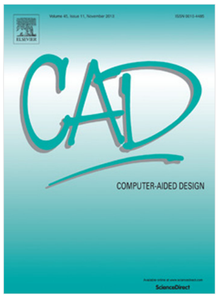

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Sebastian H. Greshake, Robert Bronsart

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Application of subdivision surfaces in ship hull form modeling

Sebastian H. Greshake[1], Robert Bronsart
University of Rostock, Germany

Abstract

The restriction of tensor-product B-splines to regular control meshes and thus four-sided surfaces is the reason that hull form modeling is still a challenge. This limitation is addressed by subdivision surfaces as they originate from the idea to define B-spline surfaces on irregular control meshes. Often subdivision is considered as a method to refine polygon meshes, but the linear nature of polygon meshes is generally not qualified for hull form representation. Therefore an introduction to the theory of generalized B-splines is given which employs the notion of subdivision to define smooth B-spline surfaces on irregular control meshes.

This article covers the application of generalized B-splines for the representation of hull forms. It is possible to represent hull forms with a single B-spline surface. The main advantage is, however, the ability to use the control mesh for modeling. It is shown that the structure of a control mesh and the principles to define a control mesh are essentially the same as for curve networks which are mostly used to define hull surfaces. In contrast to the common belief in the industry, it is analyzed that the approximation-based definition of a hull surface in terms of a control mesh simplifies modeling and improves the robustness compared to interpolation-based methods such as the commonly found interpolation of curve networks.

Keywords: Subdivision surfaces, B-spline surfaces, Ship hull form modeling

1. Introduction

One of the most important results of the ship design process is the hull form. A variety of the vessel's properties depends on the hull geometry, but its creation is still a tedious matter in existing modeling systems.

Usually bibcubic tensor-product B-splines are employed for the representation of hull surfaces. They are a reasonable choice with respect to the quality requirements. The quality is measured in terms of fairness, where this criterion requires curvature continuity and a minimal number of inflection points. The latter condition obviously applies only to the notion of curves, but the link to hull surfaces are the intersection curves of the hull with the principal planes, called lines in the context of ship design. Naturally, it is the designer's responsibility to minimize the number of inflection points, but it is favorable for this task to keep the degree of the B-spline as small as possible. In this context, a cubic B-spline offers the best trade-off between the two contradicting requirements of a minimal degree and at least curvature continuity.

Cubic B-splines are undeniably a good choice for hull form modeling, but tensor-product surfaces turn out to be a bad alternative in this context. They are strictly limited to the representation of four-sided surfaces. As a consequence, complex surfaces such as hull forms are necessarily composed of several patches.

B-spline surfaces are defined on a mesh of control points. An important property of B-splines is the intuitive link between the shape of the control mesh and the shape of the surface. However, the necessity to compose hull forms of several B-spline surfaces requires to maintain continuous transitions of neighboring patches. To realize those transitions in terms of the control mesh calls for a solid background in B-spline theory, as well as it yields complex dependencies of neighboring control meshes. As a consequence, control meshes are rarely used for hull form modeling.

In contrast, hull form modeling is commonly based on the interpolation of curve networks. The hull designer works on the level of curves rather than surfaces. The complexities of the surface generation are left to an interpolation algorithm. Most algorithms provide a reliable patch generation, but the result is often not satisfying in terms of fairness. In general only normal continuity across patch boundaries is provided by those algorithms, but curvature continuity would be required to meet the quality requirements defined above. In addition, it is difficult to minimize the number of inflection points for the hull designer because the characteristics of the input curves do generally not coincide with the characteristics of the generated surface. Interpolation is well-known to tend to oscillations. It is likely that fair input curves yield lumpy hull surfaces,

*Corresponding author.
Email address: sebastian.greshake@uni-rostock.de (Sebastian H. Greshake)