Design faster, better and more naturally with T-Splines

>The complex challenges of aircraft design illustrate the revolutionary benefits of modeling with T-Splines.

Introduction

Schuyler 'Sky' Greenawalt is a designer and the owner of School Street Design Company, which specializes in custom and prototype tooling and production of composite structures for the homebuilt and experimental aircraft community. One of his recent projects was a conceptual model for a Formula 1 Reno Racer, a small competitive aircraft designed to compete in the Formula 1 class of air races at speeds of over 200 mph.

Aircraft design poses unusual challenges for surface modelers, since the wings and tails need to be very accurate representations of airfoils, but the rest of the surfaces—fuselages and other secondary structures—need to be very smooth and fair. The blends between the two can be particularly difficult to edit and modify.

The reason for the difficulty in modeling these surfaces is not the complexity of the design. Airfoil and fuselage profiles and shapes are well understood. Rather, the challenge comes from the inherent difficulty in creating complex shapes using traditional NURBS surfacing; specifically surfaces with varying level of detail, high accuracy requirements and complex blend transitions.

Almost every surface and solid modeling application on the market today is based on a technology called non-uniform rational B-Splines (NURBS). Not until the availability of T-Splines in the last several years has there been a viable alternative technology for the designer to use. Sky was an early adopter of T-Splines and with this most recent project has transitioned to building 100% of his airplane model using T-Splines. He estimates that for a typical project he has reduced the overall time by 75% or more.
This paper explores the key reasons how T-Splines improves and speeds up the design process and how this new surfacing technology overcomes the fundamental shortcoming of NURBS.

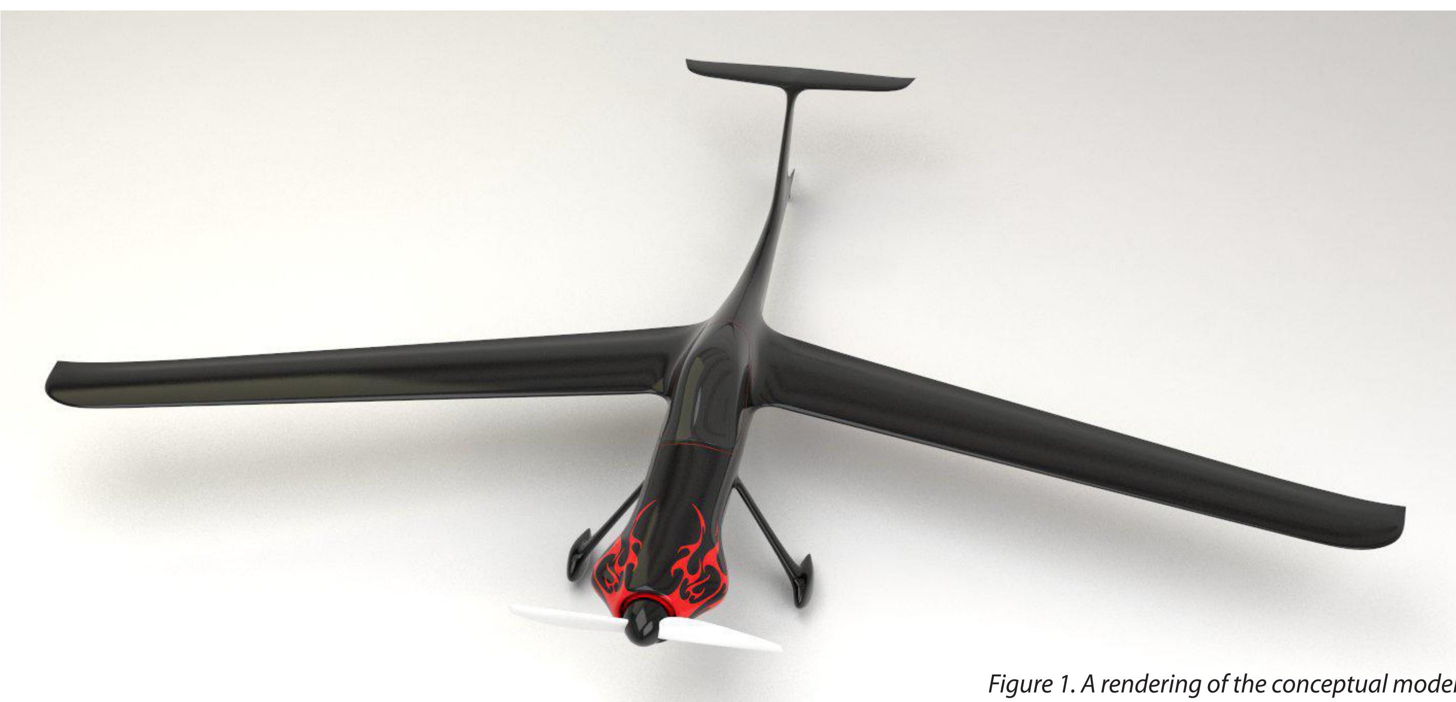

Figure 1. A rendering of the conceptual model.

The fundamental problem with NURBS

While non-uniform rational B-Splines (NURBS) provides the underlying math for nearly all surface modeling for manufacture, the implementation of NURBS in surface modeling software has some inherent limitations. These limitations become especially apparent when creating complex blends between surfaces. From the designer's perspective, the limitations of NURBS are threefold.

First, the workflow itself can sometimes feel like one is stumbling around in the dark. Typically, to create a blend between two surfaces, you first trim those surfaces, and then create guide curves or surfaces to further define the blend. Then a blend surface is created using the existing geometry as input. Only after the designer has gone quite far down the path is the quality and shape of the blend surface apparent. If the resulting surface is not acceptable, the process must be iterated until an acceptable result is obtained. Essentially, the designer is being asked to define the surface blind, which creates a lot of needless work when trying to really refine a surface.

The second problem with NURBS surfaces is that in order for blends to match up nicely at the edges, the surfaces themselves are often dense with isocurves. While the curve used to trim a surface for a blend may itself be quite simple, when that curve is projected onto the surface, the resulting edge is usually "heavy" — meaning it requires many points to be properly defined. The blend surface created with that edge as an input is likewise heavy. These blend surfaces almost always require small tweaks to get them to truly reflect the intent of the designer. However, since they are so dense with isocurves, point editing is daunting if not impossible.

Third, since most NURBS surfaces are a collection of sub surfaces or patches, changes to one can often necessitate changes to another, if not all of the other patches. This discourages the surface modeler from making changes to major portions of a model, simply because it can set off a chain reaction of changes in the rest of the model, sometimes requiring a total rebuild of the surface and creating additional cost. When designers run into these problems, they tend to think that the software platform they are running on is to blame – or that perhaps they have not fully mastered it. While this may be the case, more often they are actually bumping up against the inherent limitations of NURBS itself. Since NURBS provides the basis for surface modeling for manufacture, designers have just had to accept these limitations, as there has been no way of truly solving these design issues within the NURBS definition – until now!

Enter T-Splines

In 2003, Dr. Thomas Sederberg of Brigham Young University invented T-Splines to solve these very problems posed by the limitations of NURBS. His son, Matt, and some of his students formed a company, T-Splines, Inc., to commercialize the technology. They brought the power of T-Splines to the Rhino platform and they recently added the ability to import and manipulate T-Splines surfaces into SolidWorks with a product called tsElements for Solidworks. In a nutshell, T-Splines allows designers to add control to their surfaces in areas where they need it, but also terminate that control, so that the rest of the surface does not become needlessly heavy with isocurves – and therefore difficult to edit. This seemingly simple evolution of the NURBS architecture directly solves the problems outlined above, and allows a totally new and more intuitive workflow for surface modelers. For the designer, the truly revolutionary aspect of T-Splines is that it allows the creation of large, complex surfaces, which are one single unified element. This means that changes to one part of the model are seamlessly integrated into the surrounding geometry. The designer is free to change any portion of the model at any time, knowing that the surface will remain smooth and continuous. Since areas of detail can be terminated, typically those complex blends that were so difficult to achieve in NURBS modeling packages are now just a handful of points, which can be pushed and pulled into the designer's intended shape. Best of all, T-Splines surfaces are 100% forward and backward compatible with NURBS surfaces, so a T-Spline surface can be manufactured on all standard machines.

From Input Geometry To Topology

For the designer accustomed to working in a traditional NURBS environment, the transition to T-Splines can seem a bit daunting at first. Whereas NURBS surfaces are typically defined by lofts and sweeps – and are highly dependent on the geometry fed into these functions – T-Splines surfaces often start with "primitives" (such as boxes, spheres, and planes) which are then pushed, pulled and modified into the desired shape. Like NURBS, T-Splines surfaces employ a piecewise rectangular topology, so it becomes helpful for the designer to envision surfaces as a collection of rectangles. Unlike NURBS though, a T-Splines surface is a single continuous body, regardless of how much it is pushed, pulled or refined. The designer can completely focus on the envisioned shape, free from having to worry about dense grids, tedious point manipulations and networks of fragile surface patches.

Case Study – An Aircraft Design Using T-Splines

Sky Greenawalt has been a user of T-Splines for Rhino since 2009. He specializes in custom fabrication of composite components for the homebuilt and experimental aircraft community. Recently he began designing an entire aircraft for the Reno Air Races. While the surface model started as a mix of both T-Splines surfaces and NURBS surfaces, with NURBS blends between the two, it quickly became apparent that creating a single unified T-Spline of the entire aircraft would have many benefits.

Aircraft design poses unusual challenges for surface modelers, since the wings and tails need to be very accurate representations of airfoils, but the rest of the surfaces—fuselages and other secondary structures—need to be very smooth and fair. The blends between the two can be particularly difficult, since they often end up too heavy to point edit. Sky was wasting a lot of time in the conceptual phase of the design, simply wrestling with making nice fillets between the wing and the fuselage in NURBS. He found the quality of the blend was so dependent on the curves used to trim the fuselage that he had to undo and redo these trims over and over to get it just right. It was tedious, not always predictable, and definitely not fun.

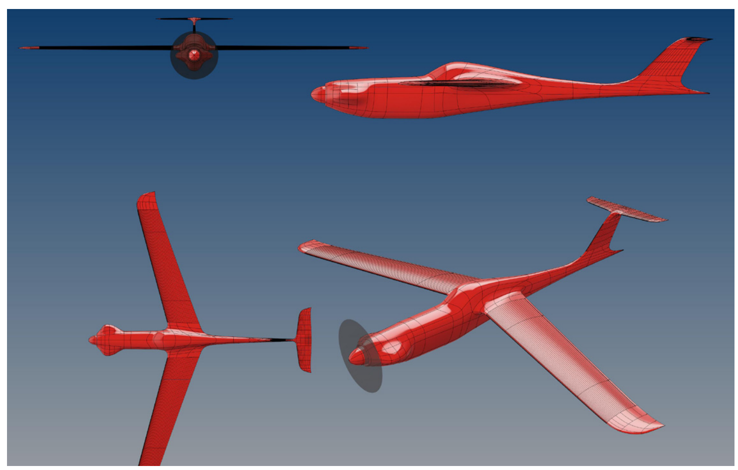

Figure 2. Aircraft body modeled as a single T-Spline surface.

Once Sky realized that he could create the entire model as one unified T-Spline surface, he found that it transformed the quality of his model, and also created a totally different workflow which saved time. He could now quickly and easily change any aspect of the model—be it the wingspan, dihedral, wing chord, fuselage width—and through it all, the model remains as one unified surface, so he did not have to go back and redefine every surface that touches that changed element. This means he can try out different ideas in a fraction of the time it would take him if he was just using standard NURBS commands.

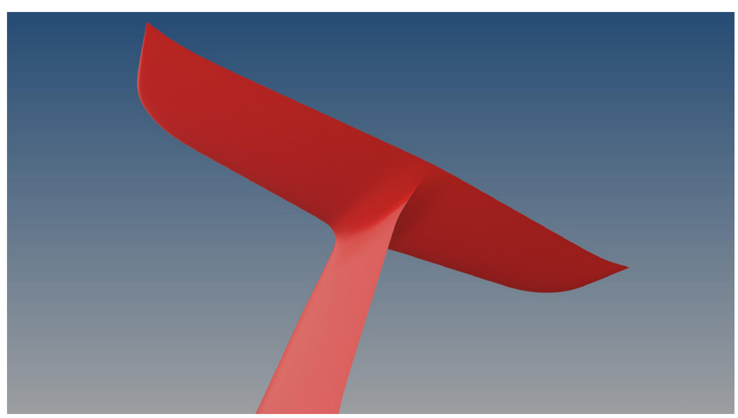

Figure 3. Tail Fin Detail.

Furthermore, the quality of the blends between those surfaces is far better than he was able to achieve using NURBS, since they are part and parcel of the model. For example, those wing-to-fuselage blends that were so difficult in NURBS are now a joy to work with. The T-points allow Sky to "thin out" the topology from the wing, which demands a high degree of accuracy. Using 32 control points on both the top and bottom wing surface, he was able to keep the wing surface to within 0.002" of the airfoil shape. However, the blend between the wing and fuselage is formed by just a handful of points—12 on each side—and Sky found he can push and pull on those points to get exactly the shape he wants. With T-Splines he gets the accuracy where he needs it, and the nice smooth and fair surfaces everywhere else.

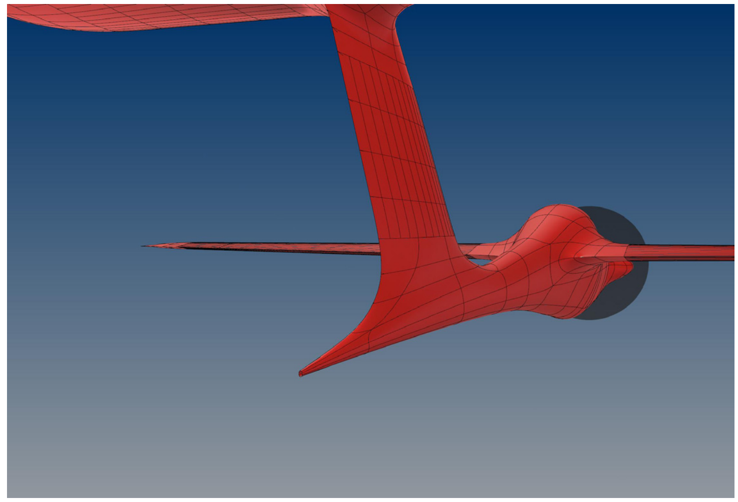

Figure 4. The image shows a nice crease fade from the rudder to the tailcone.

While making an original T-spline model is faster for Sky than doing the whole thing in NURBS, that is only part of the benefit. Where T-Splines clearly shines is in iterating. Once he has a T-Splines aircraft model created, it is far easier to make a new version of an aircraft from this master model—his experience has been that it takes 75% less time with T-Splines than with NURBS.

Conclusion

"I can say without a doubt I will never ever make another airplane in standard NURBS again," Sky concludes. "Now that I have the topology where I want it, making edits to the model and really sculpting the blends is so easy and wonderful."

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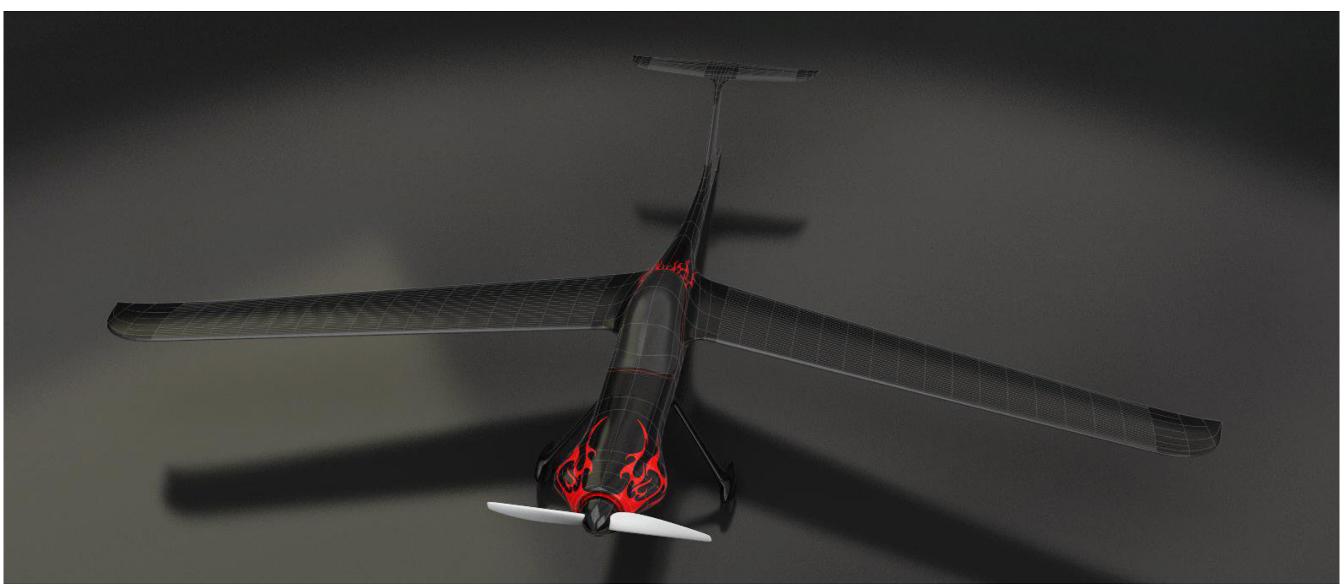

To learn more about T-Splines and how it can accelerate and improve your design process, please visit www.tsplines.com