NURBSFIX: Repairing the topology a NURBS model in view of its approximation

One-year engineer position at Inria in collaboration with GeometryFactory

Context

Because of their flexibility and accuracy, NURBS (Non-Uniform Rational Basis Spline) models have become a standard in the modeling community for generating and representing complex shapes [6]. They are made of several surface patches and a collection of curves that are used for trimming. As a direct consequence of software quirks, designer errors, and representation flaws, these NURBS models have inconsistencies that introduce small gaps and overlaps between surface patches. They are mainly located on the singularity graph of a NURBS model, near the trimming curves, especially near singularities such as sharp edges or corners.

Building a correct approximation of a NURBS model in the presence of inconsistencies is a challenging problem. Most of the current approaches are based on the repairing of the geometry of the surface patches. This requires an interactive process which is difficult to control and rarely completely successful. In this project, we will develop another approach which consists in repairing the topology of the singularity graph within a tolerance volume. This tolerance volume will be considered as a protected region that will not receive any query of geometric computations. Based on that, three types of approximations will be treated: triangular isotropic surface meshing of NURBS models, volume approximation of multi-domains delimited by NURBS surfaces, and NURBS models approximation within a given tolerance volume.
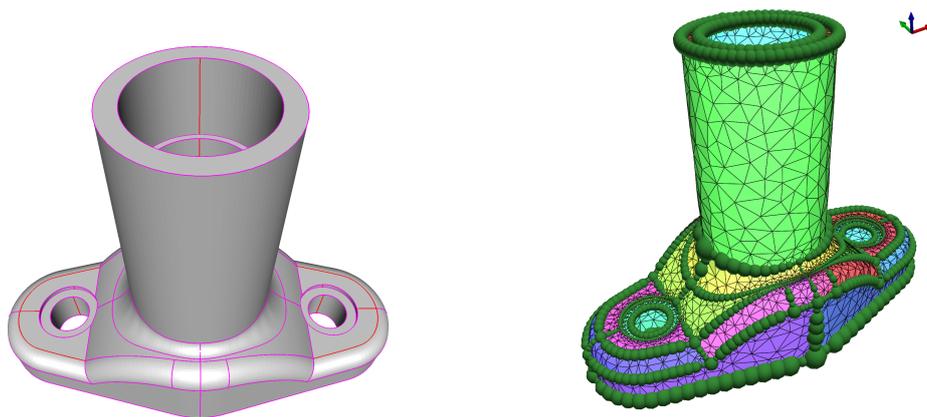

Figure 1: Meshing of a NURBS model where one can see the singularity graph which is protected within a collection of spheres.

Objectives

There are two main objectives: the repairing of the topology of a NURBS model and then its approximation.

Topology repairing. Given a NURBS model with inconsistencies, the goal is to extract a singularity graph having a *simple topology* and contained in a given tolerance region. Typically, the edges of this graph will be sharp edges, borders or non-smooth intersections, and its vertices will be cusps, darts or corners. A separation distance function will then be determined between the curves of this singularity graph, based on a conservative discretization [3]. The adjacent correspondences between patches will also be recovered or repaired if necessary.

Approximation. Building on a valid singularity graph and valid adjacent relations, the objective is to compute an approximation of a NURBS model with guarantees on its topology. The first goal is to devise a *triangular isotropic meshing* method by means of Delaunay refinement and protection of the singularity locus [1], using the CGAL mesher [5]. The interface between the mesher and the NURBS model will be done by computing intersections with lines using a new algebraic method [7]. Then, for *multi-domains* delimited by trimmed NURBS surfaces, an approximation will be computed by means of 3D Delaunay refinement. The interface with the CGAL mesher will require to define signed distance functions that are compatible with the repaired singularity graph [2]. Finally, a new method for computing an *approximation of a NURBS model within a tolerance volume* by means of an anisotropic meshing will be explored [4]. The tolerance volume will be here computed using offset computations, with control on the topology and the regularity of the surfaces defining this tolerance volume.

The engineer will be in charge of:

- Developing and implementing in C++ a reliable algorithm for detecting and protecting the singular graph of a NURBS model;
- Developing software components in the CGAL library for computing the three approximations mentioned above;
- Carrying on extensive experiments on geometric datasets;
- Implementing plugins for interactive demos.

References

[1] Oleksiy Busaryev, Tamal Dey, Joshua Levine. Repairing and meshing imperfect shapes with Delaunay refinement. In SIAM/ACM Joint Conference on Geometric and Physical Modeling, pages 2533, 2009.

[2] Tamal Dey, Firdaus Janoos, Joshua Levine. Meshing interfaces of multi-label data with Delaunay refinement. Engineering with Computers, 28:7182, 2012.

[3] Michael Guthe, Aakos Balazs, Reinhard Klein. GPU-based Trimming and Tessellation of NURBS and T-spline Surfaces. ACM Trans. Graph., 24(3):10161023, July 2005.

[4] Manish Mandad, David Cohen-Steiner, Pierre Alliez. Isotopic approximation within a tolerance volume. ACM Transactions on Graphics, Proceedings of SIGGRAPH 2015.

[5] C. Jamin, P. Alliez, M. Yvinec and J.-D. Boissonnat. *CGALmesh: a Generic Framework for Delaunay Mesh Generation.* Inria Technical report 8256.

[6] L. Piegl and W. Tiller, *The NURBS book*. Springer, Monographs in Visual Communication, 2nd edition, 1997.

[7] Jingjing Shen, Laurent Buse, Pierre Alliez, Neil Dodgson. A line/trimmed NURBS surface intersection algorithm using matrix representations. Computer Aided Geometric Design, 2016.

Partners: This project is a collaboration between the Inria project-team Aromath, the Inria project-team Titane and the SME GeometryFactory. It aims at enlarging some functionalities of the CGAL library to NURBS models. The project-team Aromath develops algebraic methods and representations for complex shapes, including NURBS models. The project-team Titane conducts researches on the modelisation and numerical treatment of 3D geometry, with a particular focus on simple representations, such as triangular or tetrahedral meshes. The SME GeometryFactory, funded in 2003, develops and commercializes various geometric software components for the Computational Geometry Algorithms Library CGAL.

Job description

Activities of the engineer:

- Implementation of a software demonstrator for CGAL: generic C++, with unit tests, examples, documentation and benchmarks.
- Implementation of an interactive demo: C++, Qt 5 and visualization via OpenGL.
- Drafting of technical reports: detailed description of technical solutions and experiments.

Qualifications and experiences:

- Engineer or equivalent degree in Computer Science.
- Experience in generic C++ programming, 3D geometric data structures and algorithms, algorithms on NURBS, rendering using OpenGL.

Skills and qualities:

- Ability to read, understand and implement research papers.
- Ability to report on experiments performed on case studies.
- Knowledge of CMake, cross-platform software development and the Qt library.
- Fluency in English (spoken and written).

Advantages:

- Restaurant on site.
- Financial participation for public transport.
- Social and sporting activities.
- French courses.

Additional information:

- Duration: 12 months.
- Targeted hiring date: March-April 2017.
- Location: Sophia Antipolis; the engineer will be a member of the Aromath Inria project-team.
- Gross Salary per month: from 2546 Euros, depending on qualifications and experiences.
- Applications must be sent before February 28, 2017.

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