Project Description: Visual editor for soft-blended skeleton-based CSG surfaces

2IMV10 Visual Computing Project: 2024 - Q3
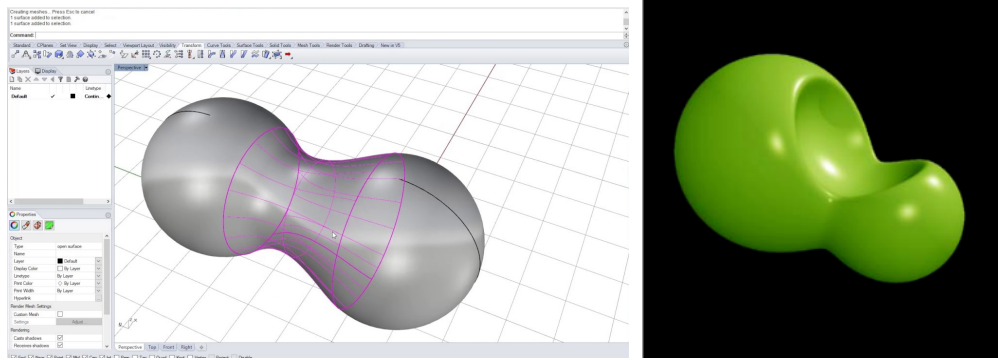

Figure 1: (left) Screenshot of a commercial 3D-modeller Rhino (only for illustration purposes); (right) soft-blended CSG surface, taken from [1].

1 Overview

This project focuses on the interactive modelling and fast rendering of implicit surfaces. Here an implicit surface is either a primitive (surface) or a compound surface. All primitives are skeleton-based surfaces: surfaces induced by an implicit function $f(x, y, z) - r = 0$, where f is the shortest distance from point (x, y, z) to any point on a skeleton and r is the distance of the surface to the skeleton. Example skeletons are a point, a line, a circle, a cylinder, a torus, etcetera. Compound surfaces are constructed by CSG operations: union, intersection, difference, and complement of surfaces. The editor should allow for interactive 3d-positioning of the skeletons and real-time rendering of the results in acceptable previews.

2 Objectives

GUI: a basic GUI with a 3D canvas, panels for application settings, render settings, ...

Skeleton-based surfaces: Implementations of the primitive surfaces

CSG operations: Implementations of boolean operations to combine surfaces

Fast rendering: Implementation of a renderer that allows interactive frame rates while manipulating the scene.

3 Learning outcomes

- Understand principles and challenges of an intuitive interactive manipulation of a 3D scene.

- Learn to design and implement algorithms and data structures for fast distance computations, object transformations, and rendering.

- Learn how to implement shading computations.

- Gain experience with implementing a GUI.

4 Scope and timeline

week 1 familiarize with background information: Lipschitz surfaces constructed with CSG expressions [1,2];

week 1 create 3D interactive program frame template.

week 2 Design 3D interactions for positioning and orientating skeletons in 3D. Render primitive surfaces accordingly.

week 3 Design 3D interactions to combine surfaces using CSG operations. Render those surfaces (don't use sphere tracing).

week 5-6 Implement fast rendering solution.

Week 7 Final presentation, including visual results and a report detailing mathematical background, algorithms, implementation choices and challenges.

5 Deliverables

- A working tool that can be used to interactively edit compound surfaces with several primitive surface types, and all CSG operations.

- A well-documented codebase and executable with instructions for usage.

- A final report summarizing methods, results, and insights gained during the project.

- A short video (teaser, 1 minute) showcasing the visual results and performance of the implementation, with an emphasis on the intuitive and interactive manipulation of surfaces.

6 References

[1] Dekkers, D., van Overveld, K. & Golsteijn, R. Combining CSG modeling with soft blending using Lipschitz-based implicit surfaces. Vis Comput 20, 380–391 (2004). https://doi.org/10.1007/s00371-002-0198-3

[2] Hart, J. Sphere tracing: a geometric method for the antialiased ray tracing of implicit surfaces. The Visual Computer 12, 527–545 (1996). https://doi.org/10.1007/s003710050084