Bridging Implicit and Explicit 3D Representations for Shape Editing

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Duration: 6 months, could be extended to a Ph.D.

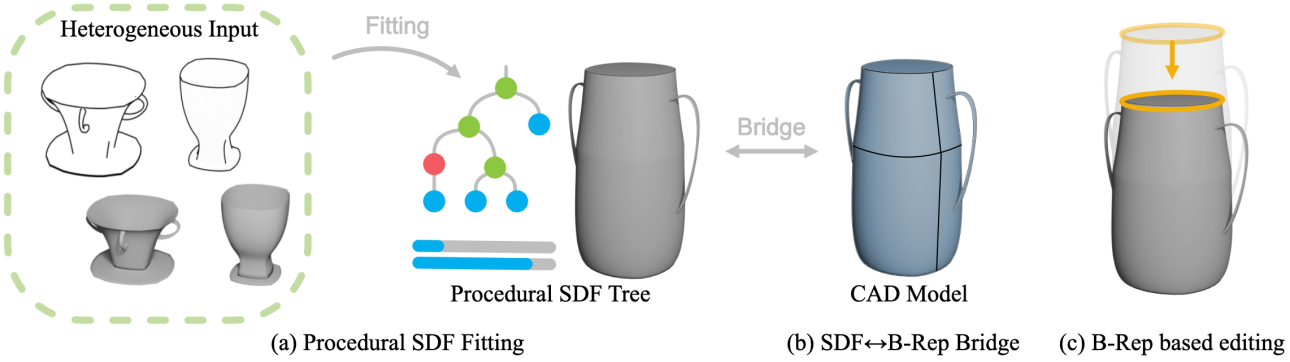


Fig 1 : Starting from heterogeneous inputs, such as 2D sketches or 3D models, our goal is to infer procedural programs expressed as CSG trees over Signed Distance Functions (SDFs) (a). By establishing a correspondence between this representation and existing boundary representations (B-Reps) used in CAD (b), we want to support precise editing through B-Rep identifiers while maintaining optimization capabilities of procedural SDFs (c).

Context and Objective

Creating high-quality 3D content remains a central challenge in computer graphics, due to the growing demand across different industries like video games, visual effects, virtual and augmented reality and manufacturing. Over the years, several 3D content representations have been developed, with strengths and limitations that make each of them more suitable for certain tasks than for others. As application fields continue to grow, a fundamental question arises: how can we select the most appropriate 3D content representation for a given task? And more importantly, is it possible to leverage the benefits of multiple representations at the same time?

For manufacturing purposes, CAD models have gained particular importance due to the precision with which geometric features can be described, especially through boundary representations (B-reps). Implicit surfaces, such as signed distance functions (SDFs), describe geometry as continuous fields over space, enabling smooth and high-resolution surface reconstruction through optimization. Moreover, both B-reps and SDFs can be expressed as procedural models to represent entire families of shapes where parameters encode variations in the shape dimensions.

Our project focuses on enabling interoperability between these two closely related representations. On the one hand, SDFs provide an implicit definition of geometry, which makes them well suited for optimization tasks but prevents direct access to individual shape features such as faces and sharp edges. In contrast, CAD models offer an explicit and precise geometric description of vertices, edges, and faces. While this explicitness enables accurate geometric control, modifying CAD models to achieve a desired target shape can be complex. **The objective of our project is to develop a unified procedural representation that combines the strengths of both approaches,** improving

interoperability between implicit and explicit modeling paradigms by enabling precise geometric operations and optimization.

Work program
A central component of this project is the design of a procedural grammar capable of representing complex shapes that is both expressive and suitable for optimization. To this end, we plan to develop a custom Signed Distance Field grammar inspired by the primitives and operators introduced by Quilez [Ini26]. Furthermore, particular attention will be given to ensuring that the grammar is compatible with gradient based optimization, following principles outlined in recent work on differentiable procedural representations [KZSS25].

The second stage of this project will focus on enabling structured editing of the procedural representations by establishing a bidirectional link between implicit Signed Distance Field (SDF) programs and explicit Boundary Representations (B-Reps). Our prior work [RMP+24] addresses this goal by introducing an explicit co-parameterization schema that enables consistent identification of surface points across procedural primitives, allowing gradient-based parameter optimization. We want to extend this approach to identify not only local surface points, but also entire geometric entities like edges and faces. By establishing a direct correspondence between procedural parameters, implicit geometry, and explicit geometric entities, we seek to enable structural information flow and interoperability between the implicit and explicit domains.

Requirements
The candidate should have studied computer graphics and/or computer vision. Experience with geometry processing and numerical optimization is a plus.

Work environment
The internship will take place at Inria Université Côte d'Azur, which is located close to Nice and Antibes. The research group GraphDeco conducts research on diverse topics in computer graphics, including geometric modeling, physical simulation, rendering: https://team.inria.fr/graphdeco/

The internship could be extended to a Ph.D. by applying for a grant at the ED STIC doctoral school.

References
[Ini26] Inigo Quilez. Distance Functions. https://iquilezles.org/articles/distfunctions/, 2026.

[KZSS25] Milin Kodnongbua, Zihan Zhang, Nicholas Sharp, and Adriana Schulz. Design for descent: What makes a shape grammar easy to optimize? ACM SIGGRAPH Asia 2025 Conference Papers. https://www.computationaldesign.group/publications/design-for-descent

[RMP+24] Marzia Riso, Elie Michel, Axel Paris, Valentin Deschaintre, Mathieu Gaillard, and Fabio Pellacini. Direct manipulation of procedural implicit surfaces. ACM Transaction on Graphics (Proc. SIGGRAPH Asia), 2024.
https://eliemichel.github.io/SdfManipulation/