Modeling 3D Surfaces Algorithmically: Exploring Signed Distance Fields for Procedural Generation

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Abstract

Beyond the widely used rasterization of triangle meshes (like visualizing 3D models with a graphics engine), ray marching signed distance fields is an intriguing method that allows for concise implementations in the field of procedural generation. While application to real-world data is not straightforward, the reliance on implicit mathematical object descriptions rather than on large software tools makes it an interesting method to explore.

A basic ray marcher can be implemented in just a few lines of code (with primitives like spheres, boxes, cylinders, tori requiring only one or two lines of code to be described), and runs easily in a pixel shader on the GPU (even using WebGl), making it popular for demoscene computer graphics artists.

Rigid transformations, mirroring and scaling are trivial (at most a matrix multiplication). Interestingly also infinite repetition of objects can be done at almost no cost. It requires nothing more than min and max to perform CSG, albeit only approximately (the resulting SDF is in general not exact).

Compactness and simplicity make this approach suitable for education. Another application is procedural generation for computer games, movies or visualizations (not necessarily for the model itself, but for supplementary content such as landscapes for flight simulators). Because the SDF can also be used for sphere collision detection, this method also works to construct solid objects in the context of haptics devices. SDFs can easily be 3D printed, if necessary converting them to a triangle mesh via marching cubes. Finally, when developing a generative modeling language (design language), SDFs provide inspiration via the form-follows-function principle.