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## Signed Distance Field (SDF)

Resources, links, papers, discussions, ShaderToys on SDF and related algorithm. Please contribute to this resource by sending your PRs!

### Tutorials / introductions

Jamie Wong, Ray Marching and Signed Distance Functions <http://jamie-wong.com/2016/07/15/ray-marching-signed-distance-functions/>

Alex Benton, Ray Marching and Signed Distance Fields <http://bentonian.com/Lectures/FGraphics1819/1.%20Ray%20M>

Sungiant, Sphere tracing signed distance functions (Scala) <https://github.com/sungiant/sdf>

Rendering Worlds with Two Triangles / with raytracing on the GPU in 4096 bytes <https://www.iquilezles.org/www/mate>

Raymarching Beginners' Thread <https://www.pouet.net/topic.php?which=7920&page=1>

Potatro, RayMarching and DistanceFields: a story of SphereTracing <https://xoofx.com/blog/2009/10/12/potatro-and-raymarching-story-of/>

Ray Marching for Dummies! <https://www.youtube.com/watch?v=PGtv-dBi2wE>

Electric Square, Raymarching Workshop <https://github.com/electricsquare/raymarching-workshop>

2D Distance fields with Unity and Unreal <https://joyrok.com/SDFs-Part-Two>

SDF Decomposition [http://zone.dog/braindump/sdf\\_clustering/](http://zone.dog/braindump/sdf_clustering/)

The smallest WebGL SDF raymarcher (135 bytes), with detailed source code and useful links [https://xem.github.io/articles/webgl\\_quest\\_2.html](https://xem.github.io/articles/webgl_quest_2.html)

SDF Generator using Compute Shaders in Unity <https://mateigiurgiu.com/unity-sdf-generator-part-1/>  
<https://mateigiurgiu.com/unity-sdf-generator-part-2/>

### Games and tools

#### Dreams

Alex Evans at Umbra Ignite 2015: Learning From Failure Dreams tech from early prototypes to cloud point rendering

<https://www.youtube.com/watch?v=u9KNtnCZDMI>

PDF: [https://www.mediamolecule.com/blog/article/siggraph\\_2015](https://www.mediamolecule.com/blog/article/siggraph_2015)

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Dreams: Under the Hood with Alex Evans! <https://www.youtube.com/watch?v=1Gce4l5orts>

Alex Evans (NVIDIA), Optimising for Artist Happiness <https://www.youtube.com/watch?v=eGfX1iWzkh0&t=1273s>

### **MagicaCSG**

Distance field editor with the same UI as MagicaVoxel by Epthtracy <https://epthtracy.github.io/index.html?page=magica>

### **<https://slimery.art/>**

SDF editor on the web <https://slimery.art/> GIF here : <https://twitter.com/DaniGatunes/status/1413388975713173506>

### **Distance Field Modeler for Unreal Engine**

<https://twitter.com/SDFmodelerUE4>

### **Antimony**

CSG (CAD) tool <https://www.mattkeeter.com/projects/antimony/3/> <https://github.com/mkeeter/antimony>

### **Clayxels**

Clayxels is the volumetric toolkit for Unity <https://assetstore.unity.com/packages/tools/game-toolkits/clayxels-165312>

### **unbound.io**

Collaborative SDF editing <https://www.unbound.io/> [https://twitter.com/unbound\\_io](https://twitter.com/unbound_io) <https://on-demand.gputechconf.com/gtc/2017/presentation/s7777-florian-hoenig-a-road-to-3d-for-everyone.pdf>

### **Claybook**

“Claybook is a unique world made entirely of clay. Shape your character and the world around you to overcome challenging obstacles.” <https://store.steampowered.com/app/661920/Claybook/>

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## Signed

Signed is a Lua based 3D modeling and construction language and will be a unique way to create 3D content, objects as well as whole scenes, in high detail. <https://github.com/markusmoenig/Signed>

## SDF pathtracer on CPU

Pathtracer written on CPU which is capable of rendering both SDF as functions and as a volume grids. The application is written on top of Yocto/GL library. <https://github.com/edu-rinaldi/Volumetric-Path-Tracer>

## Demos

Bounding Volume Hierarchy (BVH) implementation for SDFs to reduce per ray distance measurements <https://youtu.be/2T2FqvtXqLw>

SDF / Ray Marching Prototypes. A collection of SDF related examples using fungi to handle the rendering. <https://sketchpunk.bitbucket.io/>

## Algorithms / Papers

lq distance functions <https://iquilezles.undergrund.net/www/articles/distfunctions/distfunctions.htm>

Jon Baker, The Distance Estimator Compendium (many distance distance functions with awesome Fractal primitives) <https://jbaker.graphics/writings/DEC.html>

Max Norm ellipsoid (sphere with transforms) <https://www.shadertoy.com/view/Mt2XWG>

Efficient Max-Norm Distance Computation and Reliable Voxelization PDF [http://gamma.cs.unc.edu/RECONS/maxnorm](http://gamma.cs.unc.edu/RECONS/maxnorm.pdf)

Distance to Quadratic Bezier [https://twitter.com/jbaker\\_graphics/status/1415767199382396940](https://twitter.com/jbaker_graphics/status/1415767199382396940) 3D: <https://www.shadertoy.com/view/7dfGD2>

GPU-Driven Rendering Pipelines / Cluster rendering [https://advances.realtimerendering.com/s2015/aaltonenhaar\\_signatures](https://advances.realtimerendering.com/s2015/aaltonenhaar_signatures)

Making Signed Distance Field Textures With Jump Flooding Algorithm (2D) <https://blog.demofox.org/2016/02/29/fast-voronoi-diagrams-and-distance-field-textures-on-the-gpu-with-the-jump-flooding-algorithm/>  
<https://blog.demofox.org/2016/03/02/actually-making-signed-distance-field-textures-with-jfa/>

Enhanced Sphere Tracing [https://erleuchtet.org/~cupe/permanent/enhanced\\_sphere\\_tracing.pdf](https://erleuchtet.org/~cupe/permanent/enhanced_sphere_tracing.pdf)

Collection of smooth minimums, maximums, ramps, and absolutes. <https://www.shadertoy.com/view/ltf3W2>

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Segment Tracing Using Local Lipschitz Bounds (improve the marching step computation and accelerate the overall process.) <https://diglib.eg.org/handle/10.1111/cgf13951>

Improved Alpha-Tested Magnification for Vector Textures and Special Effects (Valve 2007) [https://steamcdn-a.akamaihd.net/apps/valve/2007/SIGGRAPH2007\\_AlphaTestedMagnification.pdf](https://steamcdn-a.akamaihd.net/apps/valve/2007/SIGGRAPH2007_AlphaTestedMagnification.pdf)

Massively Parallel Rendering of Complex Closed-Form Implicit Surfaces <https://www.mattkeeter.com/research/mpr/>

Tom Duff, Interval Arithmetic and Recursive Subdivision for Implicit Functions and Constructive Solid Geometry [http://fab.cba.mit.edu/classes/S62.12/docs/Duff\\_interval\\_CSG.pdf](http://fab.cba.mit.edu/classes/S62.12/docs/Duff_interval_CSG.pdf)

Raph Levien's research on 2D blurred shapes <https://raphlinus.github.io/graphics/2020/04/21/blurred-rounded-rects.html>

Interval Raymarching <https://dercuano.github.io/notes/interval-raymarching.html>

GigaVoxels: A Voxel-Based Rendering Pipeline For Efficient Exploration Of Large And Detailed Scenes [http://maverick.inria.fr/Membres/Cyril.Crassin/thesis/CCrassinThesis\\_EN\\_Web.pdf](http://maverick.inria.fr/Membres/Cyril.Crassin/thesis/CCrassinThesis_EN_Web.pdf)

Adaptively Sampled Distance Fields: A General Representation of Shape for Computer Graphics  
\_ Frisken, Perry, Rockwood, and Jones - 2000 <https://www.merl.com/publications/docs/TR2000-15.pdf>

Kizamu: A System for Sculpting Digital Characters - Frisken and Perry - 2001 <https://dl.acm.org/doi/abs/10.1145/383259>

Hierarchical hp-Adaptive Signed Distance Fields - Koschier, Deul, and Bender - 2016 <http://interactive-graphics.de/index.php/research/98-hierarchical-hp-adaptive-signed-distance-fields>

GPU-Accelerated Adaptively Sampled Distance Fields - Bastos and Celes - 2008 [https://www.researchgate.net/profile/W-Celes/publication/4344580\\_GPU-accelerated\\_Adaptively\\_Sampled\\_Distance\\_Fields/links/00b7d522f51ab59cc90000/accelerated-Adaptively-Sampled-Distance-Fields.pdf](https://www.researchgate.net/profile/W-Celes/publication/4344580_GPU-accelerated_Adaptively_Sampled_Distance_Fields/links/00b7d522f51ab59cc90000/accelerated-Adaptively-Sampled-Distance-Fields.pdf)

Signed Distance Computation using the Angle Weighted Pseudo-normal - Bærentzen and Aanæs - 2005 <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.107.9173&rep=rep1&type=pdf>

Fast Winding Numbers for Soups and Clouds - Barill, Dickson, Schmidt, Levin, and Jacobson - 2018 <https://www.dgp.toronto.edu/projects/fast-winding-numbers/>

Non-linear Sphere Tracing for Rendering Deformed Signed Distance Fields - Seyb, Jacobson, Nowrouzezahrai, and Jarosz - 2019 <https://cs.dartmouth.edu/~wjarosz/publications/seyb19nonlinear.html>

Concurrent Binary Trees (with application to longest edge bisection) <https://onrendering.com/data/papers/cbt/Concu>

Bounding Interval Hierarchies (BIH) - 2006 (for improved per Ray distance calculations) <https://people.cs.clemson.edu/~daveh/interval-WK06.pdf>

GPU accelerated BIH Construction - 2014 <https://www.uni-weimar.de/fileadmin/user/fak/medien/professuren/Virtual>

Synchronized-tracing of implicit surfaces - 2023 <https://arxiv.org/pdf/2304.09673.pdf>

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## Talks

Dynamic Bounding Volume Hierarchies (BVH methods applicable to BIH) [https://box2d.org/files/ErinCatto\\_DynamicB](https://box2d.org/files/ErinCatto_DynamicB)

Advanced-Procedural-Rendering-with-DirectX <https://www.gdcvault.com/play/1015726/Advanced-Procedural-Rendering-with-DirectX>

Advanced Graphics Techniques Tutorial: GPU-Based Clay Simulation and Ray-Tracing Tech in ‘Claybook’ <https://www.gdcvault.com/play/1025030/Advanced-Graphics-Techniques-Tutorial-GPU>  
<https://www.youtube.com/watch?v=Xpf7Ua3UqOA>

Rendering mandelbox fractals faster with cone marching <https://www.youtube.com/watch?v=4Q5sgNCN2Jw&t=530s>  
[http://www.fulcrum-demo.org/wp-content/uploads/2012/04/Cone\\_Marching\\_Mandelbox\\_by\\_Seven\\_Fulcrum\\_Long](http://www.fulcrum-demo.org/wp-content/uploads/2012/04/Cone_Marching_Mandelbox_by_Seven_Fulcrum_Long)  
<https://www.pouet.net/prod.php?which=59072>

Conemarching in VR / Developing a Fractal experience at 90 FPS / Johannes Saam / Mariano Merchante / FRAMESTORE [https://ubm-twvideo01.s3.amazonaws.com/o1/vault/gdc2018/presentations/Saam\\_Johannes\\_Merchante](https://ubm-twvideo01.s3.amazonaws.com/o1/vault/gdc2018/presentations/Saam_Johannes_Merchante)  
<https://www.gdcvault.com/play/1025454/Cone-Marching-in-VR-Developing>

Fluid and Particle Physics in PixelJunk Shooter. 2D fluids collision detection with SDF <https://www.gdcvault.com/play/1015726/Fluid-and-Particle-Physics-in-PixelJunk-Shooter>  
With-the-Flow-Fluid

Realtime sparse Distance Fields for game <https://gpuopen.com/gdc-presentations/2023/GDC-2023-Sparse-Distance-Fields-For-Games.pdf>

## Twitter/Reddit discussions

BVH with blending <https://twitter.com/TheKristofLovas/status/1415000116629495808>

fBM style displacement Inigo quilez @iquilezles <https://twitter.com/iquilezles/status/1414738043118899200>  
<https://iquilezles.org/www/articles/fbmsdf/fbmsdf.htm>

How is SDF stored in a octree? [https://www.reddit.com/r/VoxelGameDev/comments/ontjdf/how\\_is\\_sdf\\_stored\\_in\\_a\\_octree/](https://www.reddit.com/r/VoxelGameDev/comments/ontjdf/how_is_sdf_stored_in_a_octree/)

Using @SebAaltonen’s eikonal solver (<https://shadertoy.com/view/ltGGRw>) to fix interior/exterior of SDF after add/cut. <https://twitter.com/Calneon/status/1422316033071882243>

Casey Muratori’s helpful notes for Implicit Surfaces and Interval Arithmetic <https://hastebin.com/raw/orenawiwum>

“my best idea right now is to start in the middle of the ray/bounds intersection, and add new samples at the half way point of every unknown segment of the ray until you find a hit with no unknown space preceding it” <https://twitter.com/ladyaeva/status/1201770482766364672>

“the idea here is that you start at the graph leaves and work your way down to the graph root. leaves emit geometry for basic shapes. operators modify the mesh data, and so on.” <https://twitter.com/ladyaeva/status/1410120245621239808>

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## Code

hg\_sdf A glsl library for building signed distance functions by Mercury [https://mercury.sexy/hg\\_sdf/](https://mercury.sexy/hg_sdf/)

Rust & Vulkan test projects. “The first test project renders 1 million cubes, each containing a 950 MB (uncompressed) distance field volume. The second test project is going to be using sparse octree storing a hierarchy of distance field volume bricks.” [https://github.com/sebbbi/rust\\_test](https://github.com/sebbbi/rust_test)

libfive is a software library and set of tools for solid modeling, especially suited for parametric and procedural design. <https://libfive.com/>

## Conversion to Polygonal Mesh

isosurface: A project testing and comparing various algorithms for creating isosurfaces <https://github.com/Lin20/isosurface>

Manifold Dual Contouring - *Schaefer, Ju, and Warren - 2007* <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1.1.1.1>

Dual Contouring Tutorial <https://www.boristhebrave.com/2018/04/15/dual-contouring-tutorial/>