#### **Printing Algorithmic Objects** Julia Sets, DLA, Fluids

Mark J. Stock Boston 3D Printing Meetup, Somerville, MA 2016-06-27



The Julia Set

#### **Diffusion-Limited Aggregation**

Molecules

**Computational Fluid Dynamics** 

# Best Technology For Fractals?

- For home: FDM (low cost and easy) (I like the Printrbot Simple)
- For work: SLS or glued gypsum (ability to print craziest shapes/colors)

#### The Julia Set

```
The Julia Set
```

// for every i,j,k in 3D volume, do

```
cnt = 0; z1[] = \{x, y, z, 0.0\} // z1 is f(i, j, k)
```

while (forever)

```
z0[] = z1[]
```

```
z1[0] = z0[0]*z0[0] - z0[1]*z0[1] 
- z0[2]*z0[2] - z0[3]*z0[3] + julia[0] 
z1[1] = 2.0*z0[0]*z0[1] + julia[1] 
z1[2] = 2.0*z0[0]*z0[2] + julia[2] 
z1[3] = 2.0*z0[0]*z0[3] + julia[3]
```

```
if (VecMag(z1) > cutoff) break
if (++cnt > maxIters) break
```

end

out[i][j][k] = (cnt > maxIters) ? 1.0 : 0.0





#### Problem: Infinite Detail

# How do we manifest something with infinite surface area?

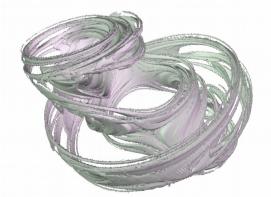


With cutoff ~4, any maxIters > 20 gives too much detail!

#### Allowed Iterations vs. Shape



4 iters



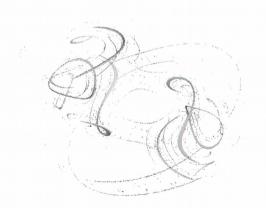
16 iters



8 iters



12 iters





32 iters

Julia Sets with x=-0.4 y=0.4 z=0 w=0.6

#### Julia Set in 3D



#### Julia Set in 3D



#### Julia Set in 3D



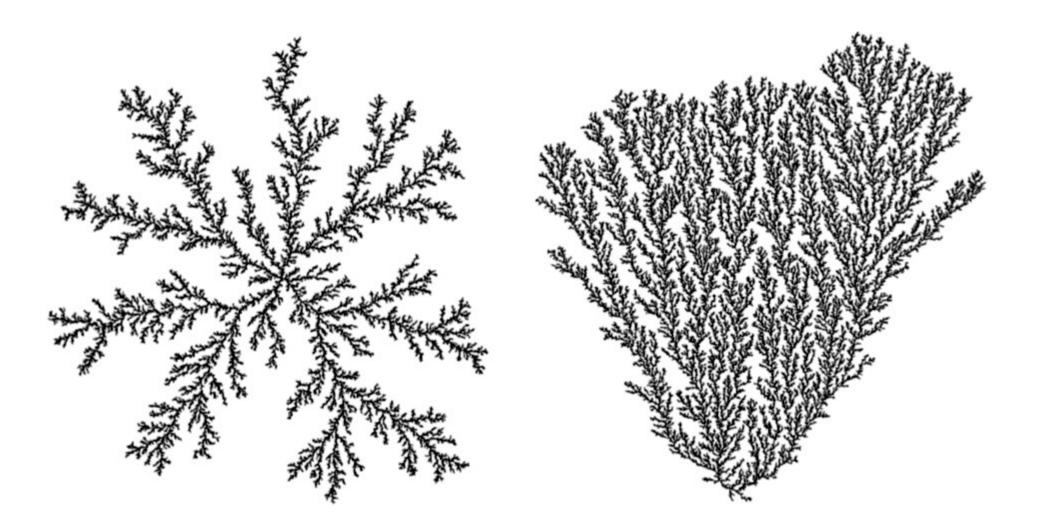
#### Diffusion-Limited Aggregation

### Diffusion-Limited Aggregation

T. Witten and L. Sander, *Physical Review B* **27**, 5686-5697 (1983)

- 1. Begin with fixed particle at 0,0[,0]
- 2. Random-walk new particle until it contacts any fixed particle
- Fix that particle at the contact pt
   Goto 2.

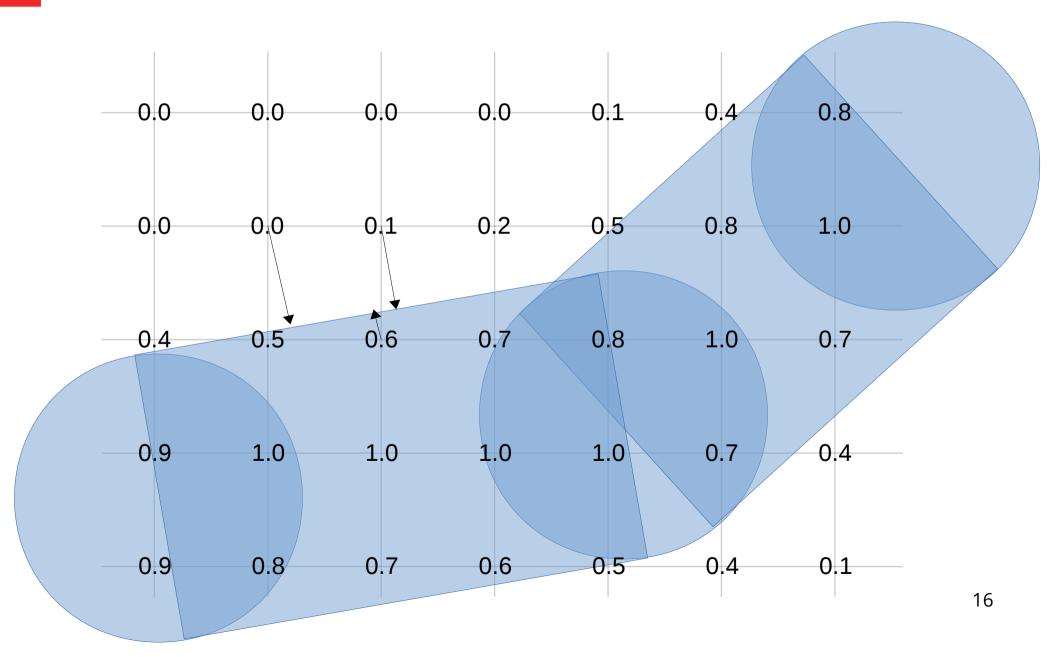




# DLA: Closing The Mesh

- 1. Start with DAG data
- 2. Calculate radius for each segment
   (try c\*weight^(1/D))
- 3. Trim tips to reduce complexity
- 4. Convert to rasterized (voxel) grid\*
- 5. Isosurface to generate triangle mesh

#### DLA: 3D Rasterization



#### DLA: 3D Rasterization Tips

SLS (nylon) is the best only material

Keep cylinders >0.8 mm diameter

Have >3 voxels across narrowest geom

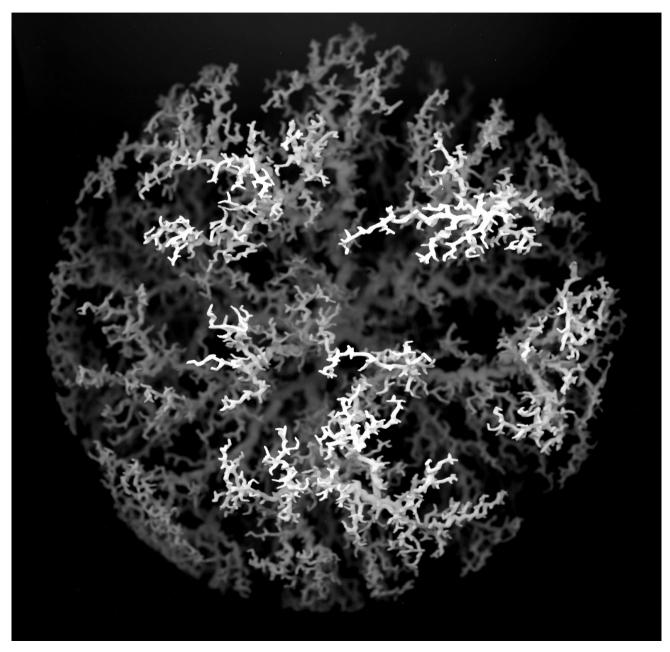
#### DLA in 3D



#### DLA in 3D



### DLA in 3D



#### Full-Color Molecules

### Full-Color Molecules

#### 1. Download and install VMD

http://www.ks.uiuc.edu/Development/Download/download.cgi?PackageName=VMD

2. Download .pdb file for molecule and open

http://www.nyu.edu/pages/mathmol/library/drugs/ http://www.rcsb.org/pdb/home/home.do

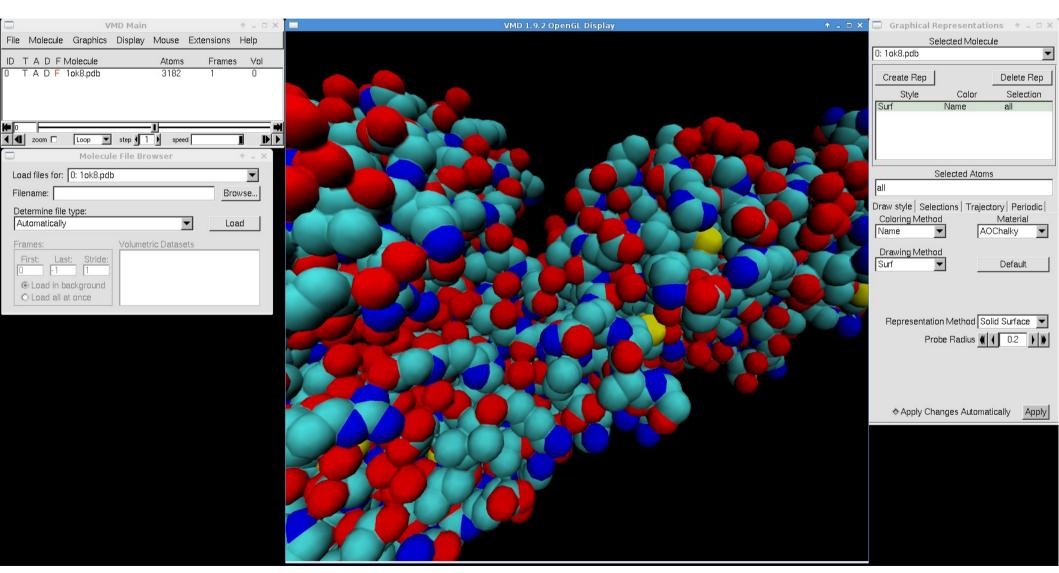
#### 3. Set Graphics->Representations to Surf/Quicksurf

- 4. Set Display->Axes->Off
- 5. File->Render->X3D
- 6. Some repair may be necessary

#### Dengue Virus (QuickSurf)

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Molecule File Browser	↑ _ ×		
Load files for: 0: 1ok8.pdb	<b>_</b>		Selected Atoms
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Determine file type: Automatically	Load		Coloring Method Material
Frames: Volumetric Datasets First: Last: Stride: 0 -1 1 © Load in background			Drawing Method QuickSurf  Default
O Load all at once			Resolution 0.50 Radius Scale ((0.7))
			Density Isovalue
			Grid Spacing
1			Surface Quality Max
			Apply Changes Automatically Apply

#### Dengue Virus (Surf)



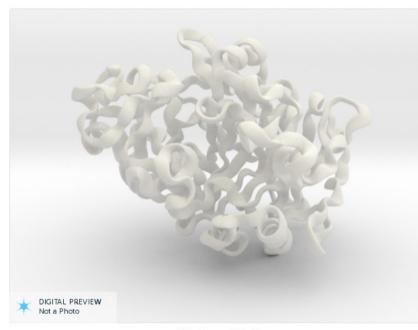
### Dengue Virus (Ribbons)

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#### Complex Biomolecule (Ribbons)



Vmdribbons by MarkJStock TVisit Shop



White Strong & Flexible



About this Product

🛇 What's in the Box

Not For Sale



#### More From MarkJStock





Cubic Dendrite, 2/50 \$1,073.52

Triple Fluid Collisio... \$286.42





IN

4D Quaternion Juli... \$468.52



#### Computational Fluid Dynamics

#### Computational Fluid Dynamics

# 2D? Easy to compute, can print heightfield3D? Hard to compute, but what to print?

Solution: Drop a dimension: use lines and surfaces

#### 2D Simulation to 3D Print

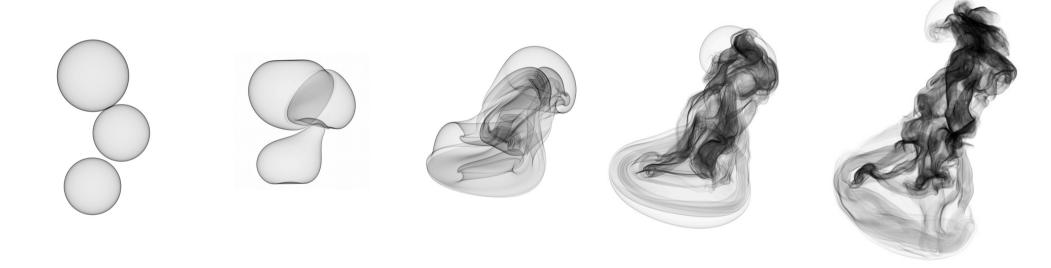


#### De-Volumizing 3D Flows

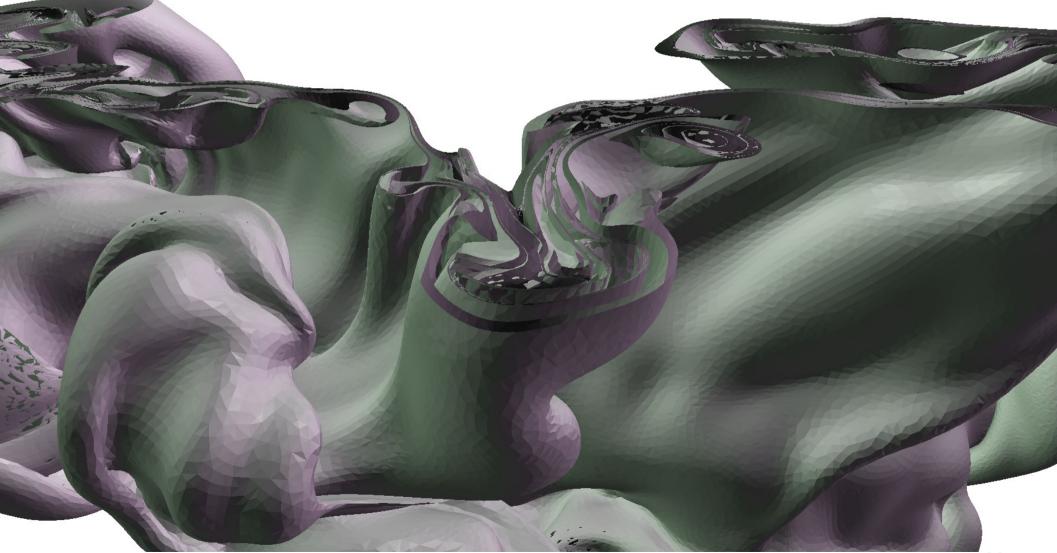
- Computational elements are lines and surfaces
- Tracked particles become lines (streamlines)
- Tracked lines become surfaces (streamsurface)

Re-volumize for printing with voxel rasterization

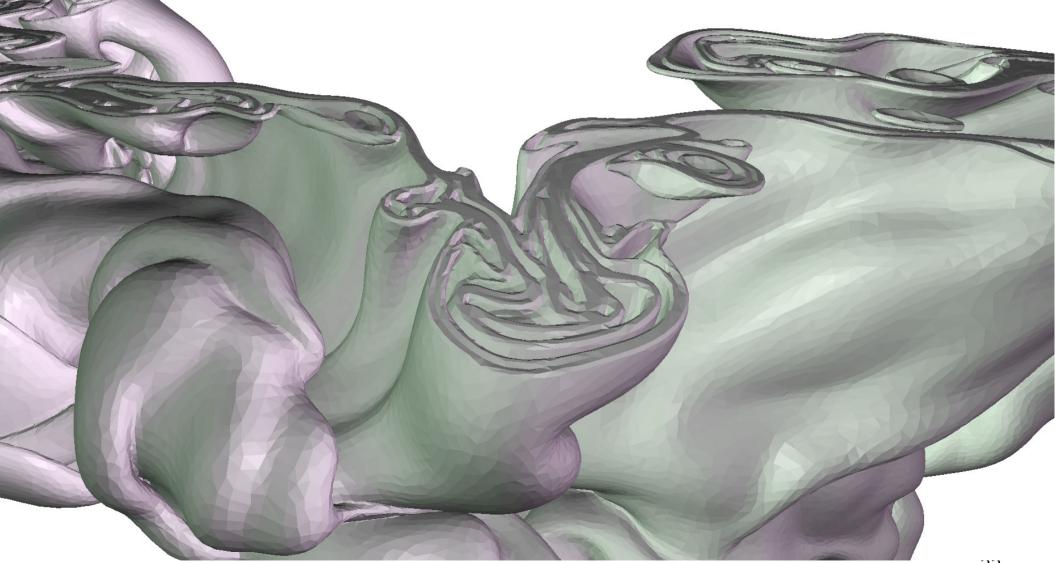
#### Vortex Sheet Simulations



#### Vortex Sheet (Raw)



#### Vortex Sheet (Re-Volumized)



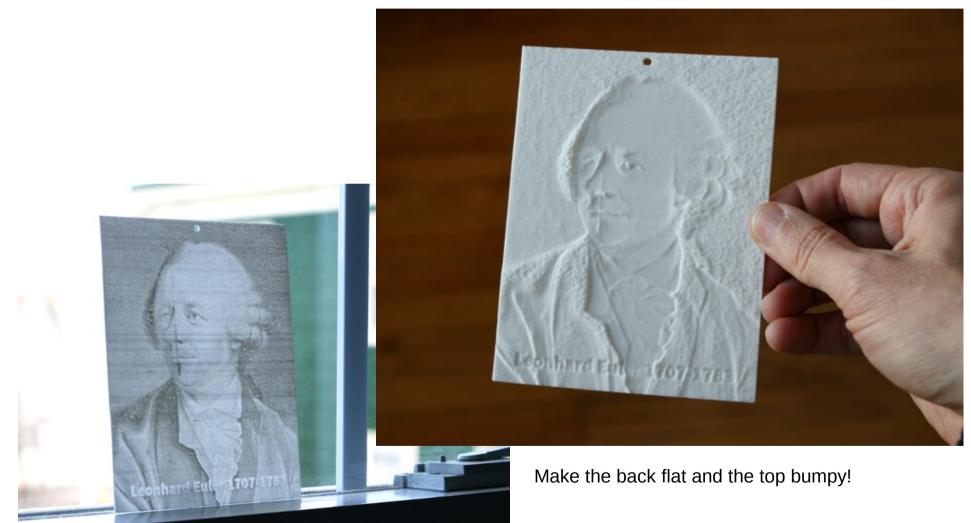
#### Vortex Sheet (In SLS Nylon)



#### Vortex Sheet (In SLS Nylon)



#### Lithophane



http://www.shapeways.com/shops/rocketscigifts



- 3D printing is easier & cheap now
- Smooth away the fine detail, either via algorithm or post-process
- Use online tools for modeling, sharing (Meshlab, Autodesk 123D Make, Shapeways...)

#### Thank You

# markjstock

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