STU SvF

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3D point cloud surface reconstruction by using level set methods

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In this work we created a mathematical model and numerical method for surface reconstruction from 3D point cloud data, using the level-set method. The method was implemented in the programming language C and tested on representative examples as well as complex real data.

Mathematical formulation

The level set method, which we are using is based on the solution of the advection equation with the curvature term

$$u_t - \nabla d \cdot \nabla u - \delta \left|\nabla u\right| \nabla \cdot \left(\frac{\nabla u}{\left|\nabla u\right|}\right) = 0$$

$$(x,t) \in \Omega \times [0,T]$$

This equation is coupled with homogeneous Neumann boundary conditions and an initial condition.

Numerical solution

The numerical solution consists of the following steps

- Calculation of the distance function to the point cloud $\Omega_0 \subset \Omega$
- Finding an initial surface which contains Ω_0.
- Generation of the final solution of the equation.

Calculation of the distance function

For the calculation of distance function we use the Fast sweeping method, which solves the Eikonal equation with boundary conditions:

$$\left|\nabla d\left(x\right)\right| = f\left(x\right) \quad x \in \Omega$$

$$d\left(x\right) = 0 \quad x \in \Omega_0 \subset \Omega$$

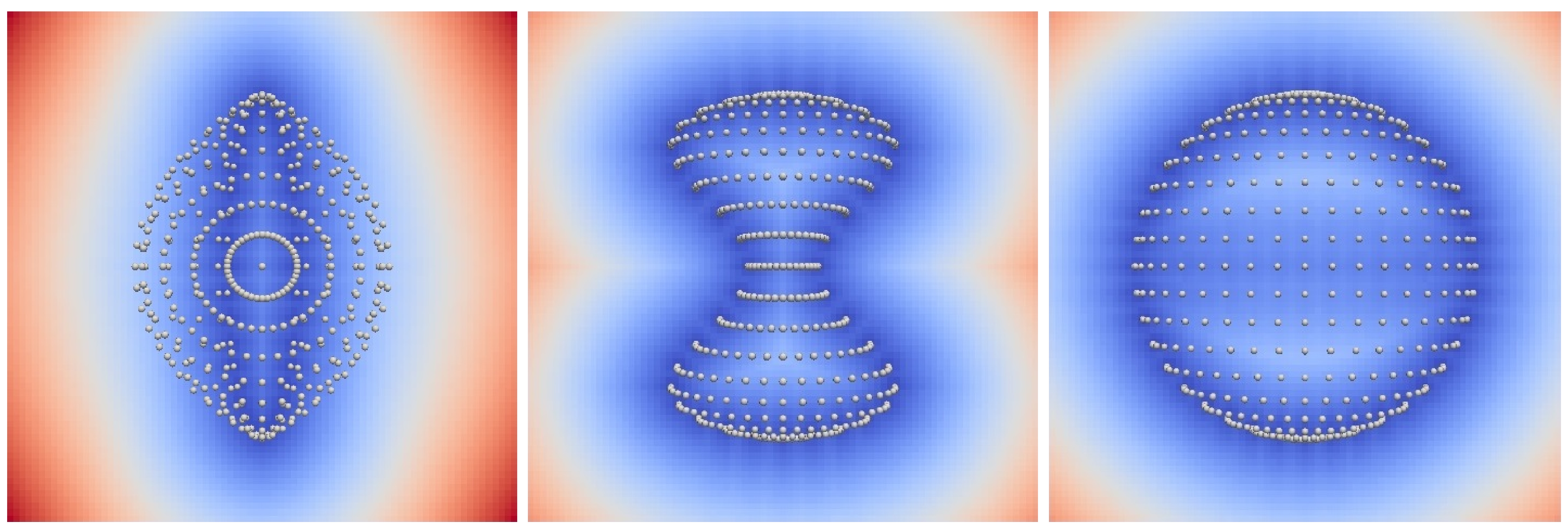

Figure 1: Distance function with point cloud data. On the left we see the distance function on the plane $z = 0$, in the middle the plane $y = 0$ and on the left the plane $x = 0$.

The initial condition

Theoretically any initial surface that contains the point cloud data set could be used as an initial condition, but an optimal initial guess is crucial for the efficiency of the method.

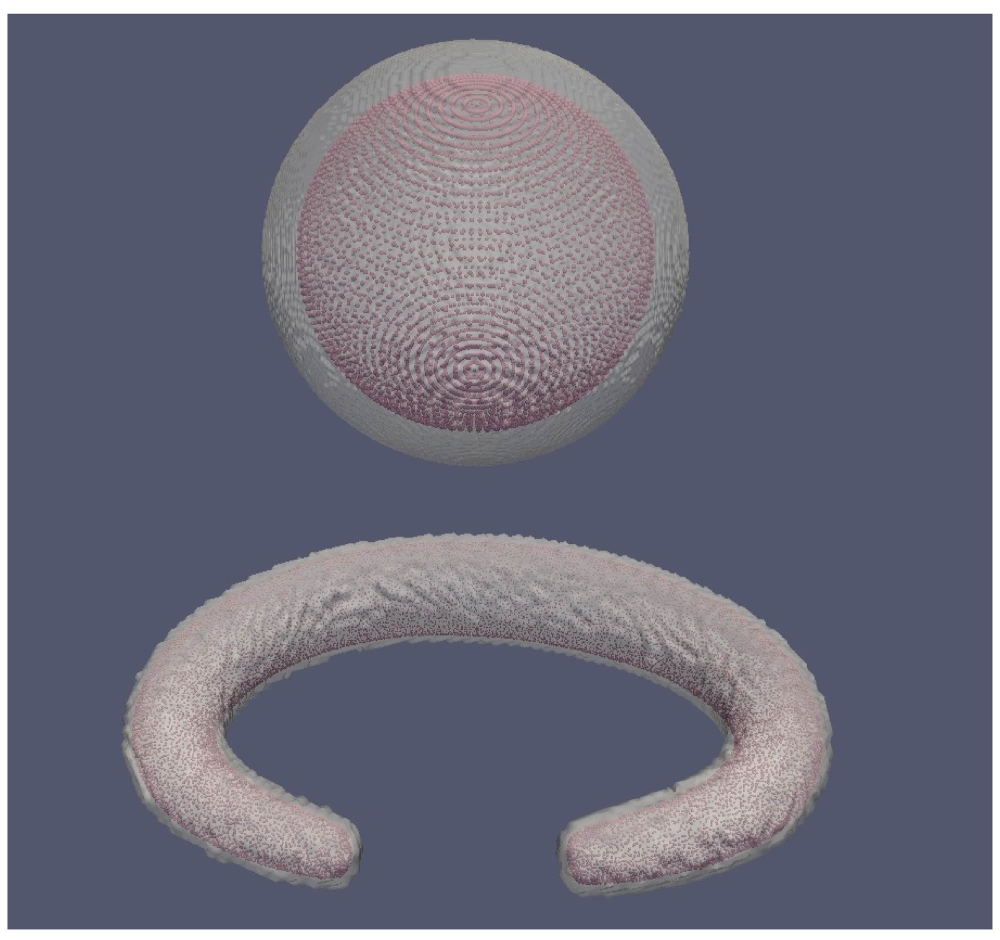

Figure 2: Examples for the initial condtition used in our method

Numerical results

After we implemented the method in the programming language C we tested it on representative examples as well as real data.

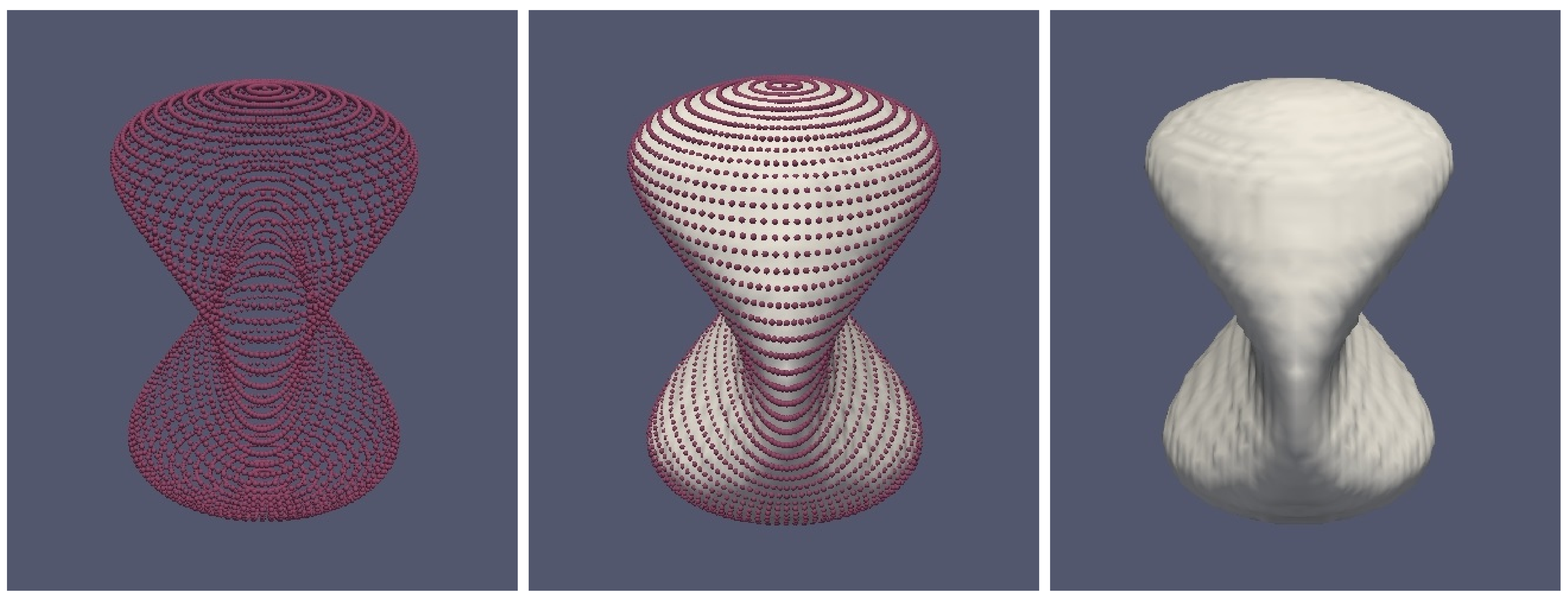

Figure 3: Test object. On the left we see the point cloud data, in the middle the point cloud with the final model and on the right the final model only.

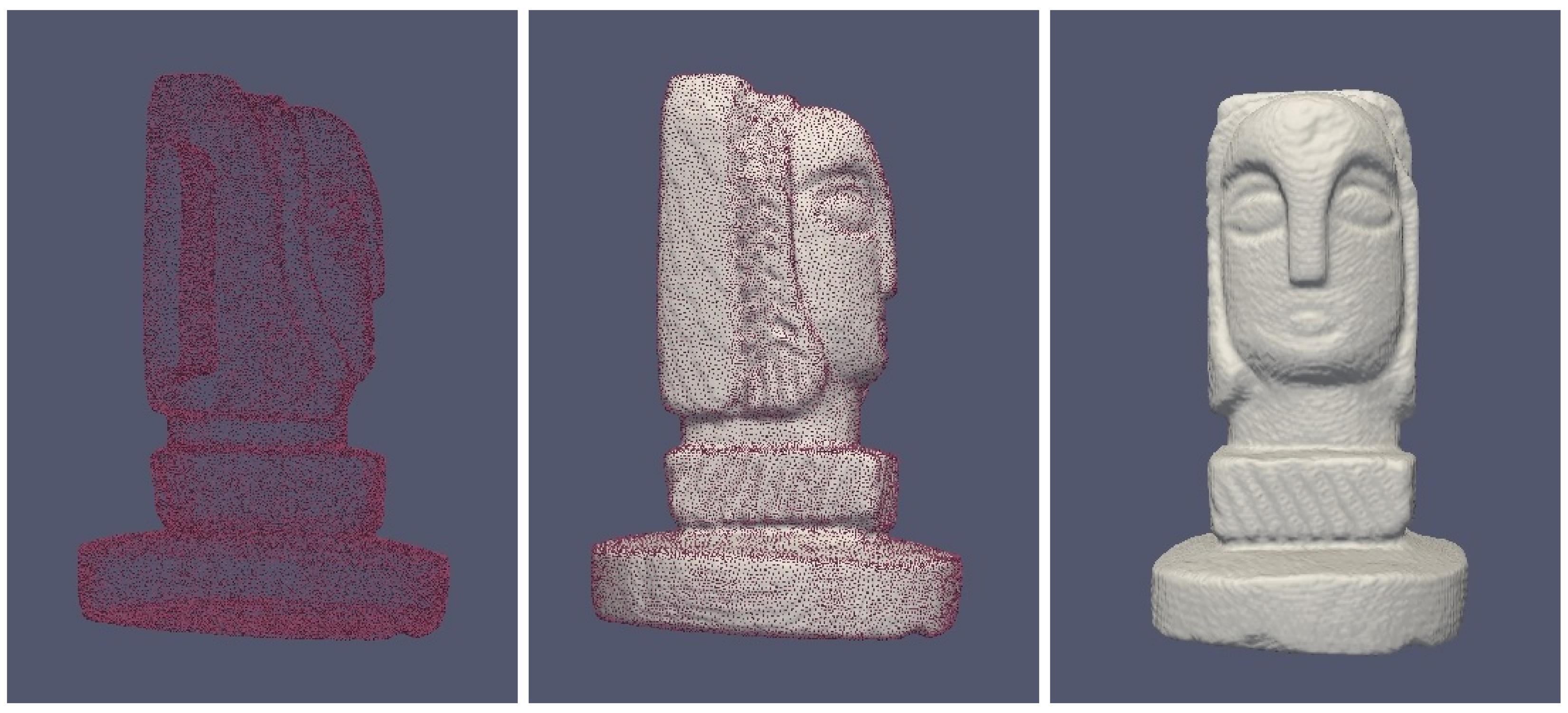

Figure 4: Archaeological finds: sealer. On the left we see the point cloud data, in the middle and the right the final result from different viewpoints.

Figure 5: Angel statue. On the left we see the original object, on the right the result of reconstruction by our method.

Computation acceleration

We construct a band around the area between the initial surface and the point cloud data, so we can calculate the final solution only in this new subset of all grid cells.

Number of grid cells	Points in band	CPU time (s) Original	CPU time (s) Optimized	Mean squared difference
40^3	6 075	13.914	0.537	1.75849e-6
80^3	48 710	88.673	3.470	4.38982e-8
160^3	392 185	2 051.402	72.846	9.36878e-9

Table 1: CPU times comparison for the sealer data set

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