Poisson Surface Reconstruction

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1 Progress

1.1 Background

Poisson surface reconstruction is an implicit method that uses a given set of orientated points ($\vec{V}$) and approximates the possible shape of the surface (δM). Our target is to model an indicator function (χ_M) that decides whether a certain point belongs inside or outside the object (M). That way, we can locate the surface of the object by detecting where the indicator function changes ($\nabla \chi_M = 0$)

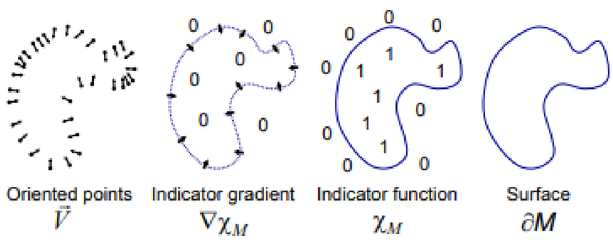

Figure 1. 2D Poisson Surface Reconstruction Example

$$\chi_M(x) = \begin{cases} 0, & x \in M \\ 1, & x \notin M \end{cases} \tag{1}$$

Fundamentally, we want the gradient of the indicator (which represents the directions of maximum change) to coincide with the normal field, approximated by the oriented points, by minimizing $||\nabla \chi - \vec{V}||$. Thus, we wish to solve:

$$\Delta \chi = \nabla \cdot \nabla \chi = \nabla \cdot \vec{V} \tag{2}$$

As the indicator function is a piece-wise function, we can differentiate a smoothed version of χ_M by convolving χ_M with a smoothing filter, F which roughly retains the position of the surface while still being differentiable.

The location of the step implicitly defines the surface. Applying a convolution operation allows us to take the gradient. Fundamentally, we want the gradient of the indicator (which represents the directions of maximum change) to coincide with the normal field, approximated by the oriented points. This happens when the Laplacian of the indicator best matches the divergence of the normal field, giving us a Poisson partial differential equation. Using an octree spatial partition and assigning a basis function at each leaf node allows us to approximate the normal vector field. To solve the Poisson equation, we minimize the projection of the two sides of the equation on the function space defined by the basis functions. Expressed in matrix form, it results in a least-squares problem. The solution allows us to obtain the value of the indicator function at any point, and we can use the marching cubes algorithm to get our final mesh.

1.2 Experimentation

One of our goals was to experiment with how Poisson surface reconstruction handles point clouds containing multiple objects, intending to modify it to support these cases if it doesn't already. We discovered situations where the algorithm would try to connect distant points from the input. However, this only occurred if there were no vertex normals that disagreed with the surface. For example, consider the mesh in Figure 2. Poisson surface reconstruction connects the two objects because each cube is missing the face closest to the other cube. If the cubes have six faces, the reconstruction will not connect them.

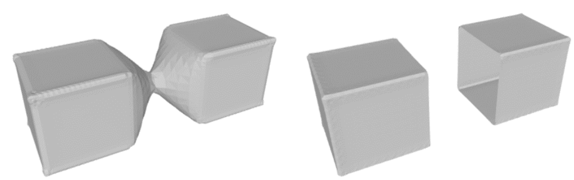

Figure 2. Surface reconstruction with and without clustering

We have been working on extending Poisson surface reconstruction to handle these cases using clustering. Currently, the number of objects has to be known, and our algorithm partitions the point cloud into the most likely distribution given this information. As a result, we can generate surfaces that do not attach to each other.

There are a few uses for this refined approach to surface reconstruction. First, it can support open objects. While Poisson surface reconstruction can already handle shapes such as spheres or cubes, our method also allows for reconstructing clothes or paper together in a scene. Also, this algorithm allows for the creation of individual object meshes. Instead of a single surface file representing the entirety of the point cloud, this approach creates a surface for each specified object, which provides greater flexibility in different use cases. For example, surfaces for a large number of objects in a single point cloud can be computed simultaneously.

2 Reflection

Understanding the math behind Poisson surface reconstruction proved to be more difficult than we expected. We've taken more time to fully comprehend the theory behind it, and as a result, we're somewhat behind on our initial plan to implement the algorithm.

3 Updated Plan

We believe we will be able to code Poisson surface reconstruction in the next week, slightly pushing back our schedule. If all goes well, we should still be able to deliver the same objectives as in our proposal.