A volumetric method for building complex values from range images

Brian Curless and Marc Levoy, “A Volumetric Method for Building Complex Models from Range Images,” *Proceedings of the 23rd annual conference on Computer graphics and interactive techniques - SIGGRAPH ’96*, 1996, 303–12

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Praktikum GPU Programming WS1415

Range Image

Range images are formed by sweeping a 1D or 2D sensor linearly or circularly around an object.

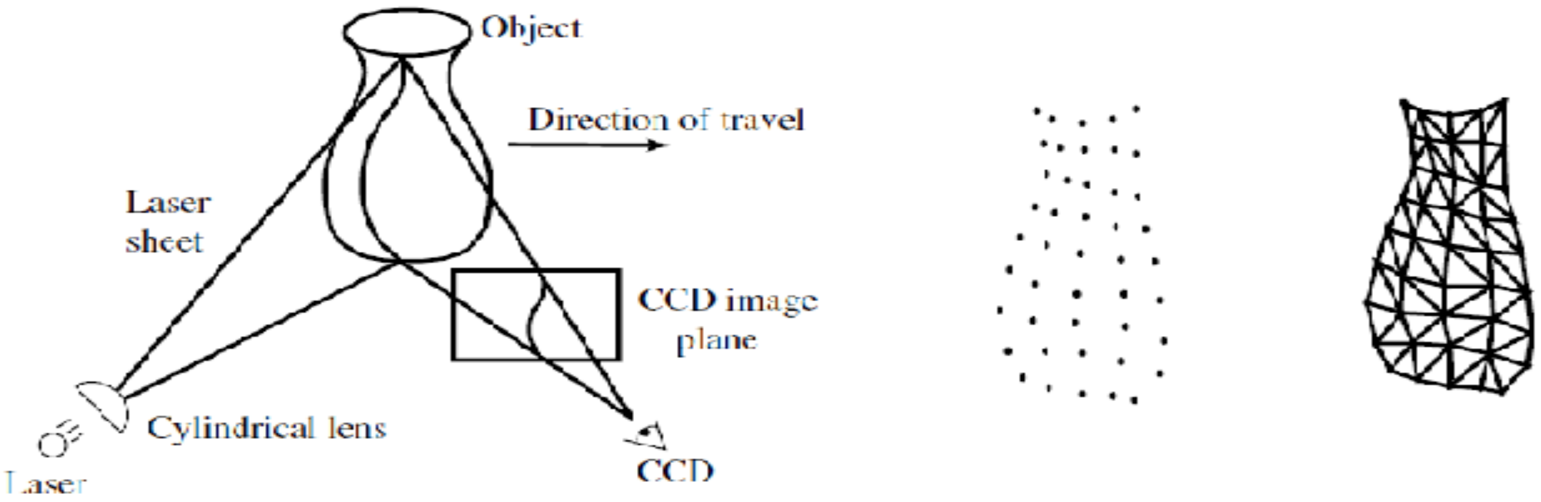


Figure : illustrates how an optical triangulation scanner can be used to acquire a range image.

Introduction

- Technique for reconstructing surfaces by integrating groups of aligned range images.
- Volumetric integration of range images consisting of a cumulative weighted signed distance function by fast volume traversal
- Fast surface reconstruction using marching cube algorithm

Approach

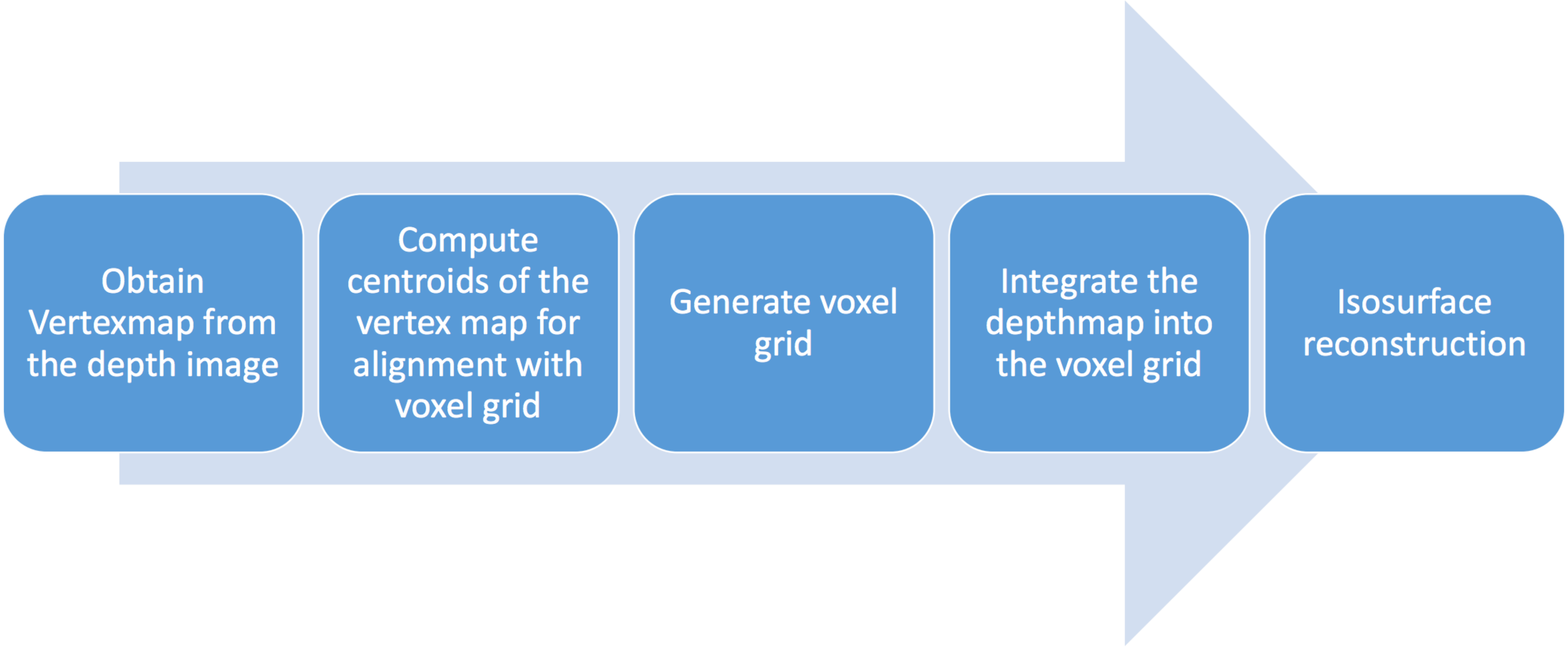
- Consider a continuous implicit function D(x)
- Obtain a cumulative signed distance function $d_1(x)$, $d_2(x)$... $d_n(x)$, a cumulative weight for each voxel $w_1(x)$,$w_2(x)$...$w_n(x)$
- update the sdf and weights using the formula –

$$D_{i+1}(\mathbf{x}) = \frac{W_i(\mathbf{x})D_i(\mathbf{x}) + w_{i+1}(\mathbf{x})d_{i+1}(\mathbf{x})}{W_i(\mathbf{x}) + w_{i+1}(\mathbf{x})}$$

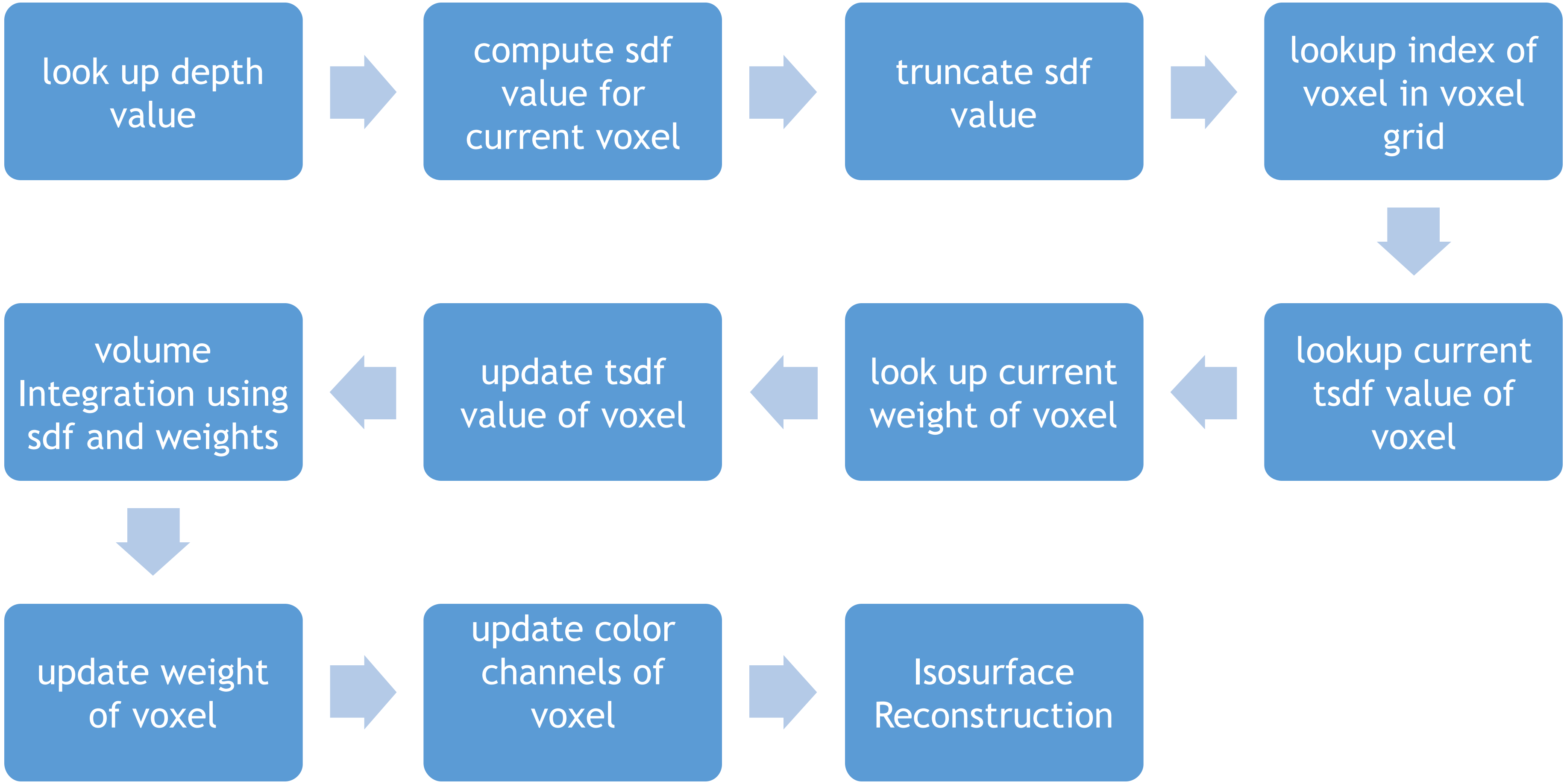
$$W_{i+1}(\mathbf{x}) = W_i(\mathbf{x}) + w_{i+1}(\mathbf{x})$$

- represent these functions on a discrete voxel grid and extract an isosurface corresponding to D(x)

Algorithm Overview



Software Flow



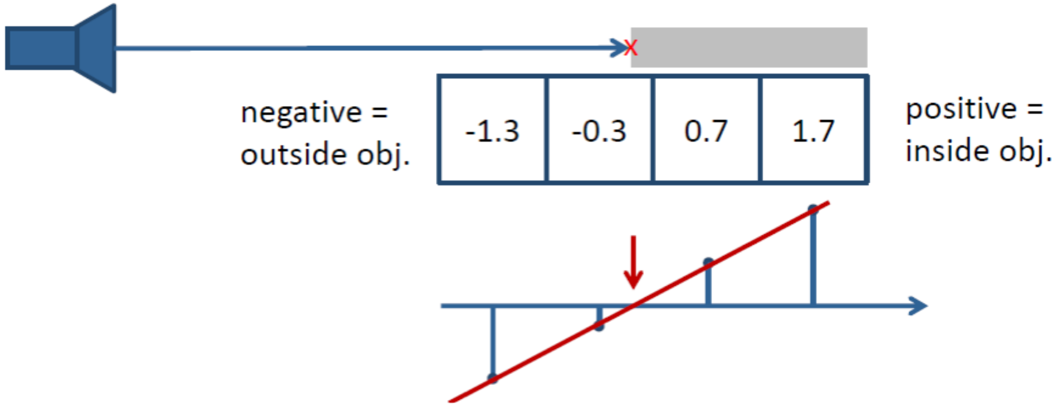
Computing the 3D surface points

Given the depth image d, compute the 3D surface point using

$$\begin{pmatrix} (x - c_x)\frac{\mathcal{Z}_t(x,y)}{f_x} \\ (y - c_y)\frac{\mathcal{Z}_t(x,y)}{f_y} \\ \mathcal{Z}_t(x, y) \end{pmatrix}$$

Signed Distance Function(sdf)

Determines the distance of a given point x from the boundary of an object



SDF is constructed from the depth images and the corresponding camera pose

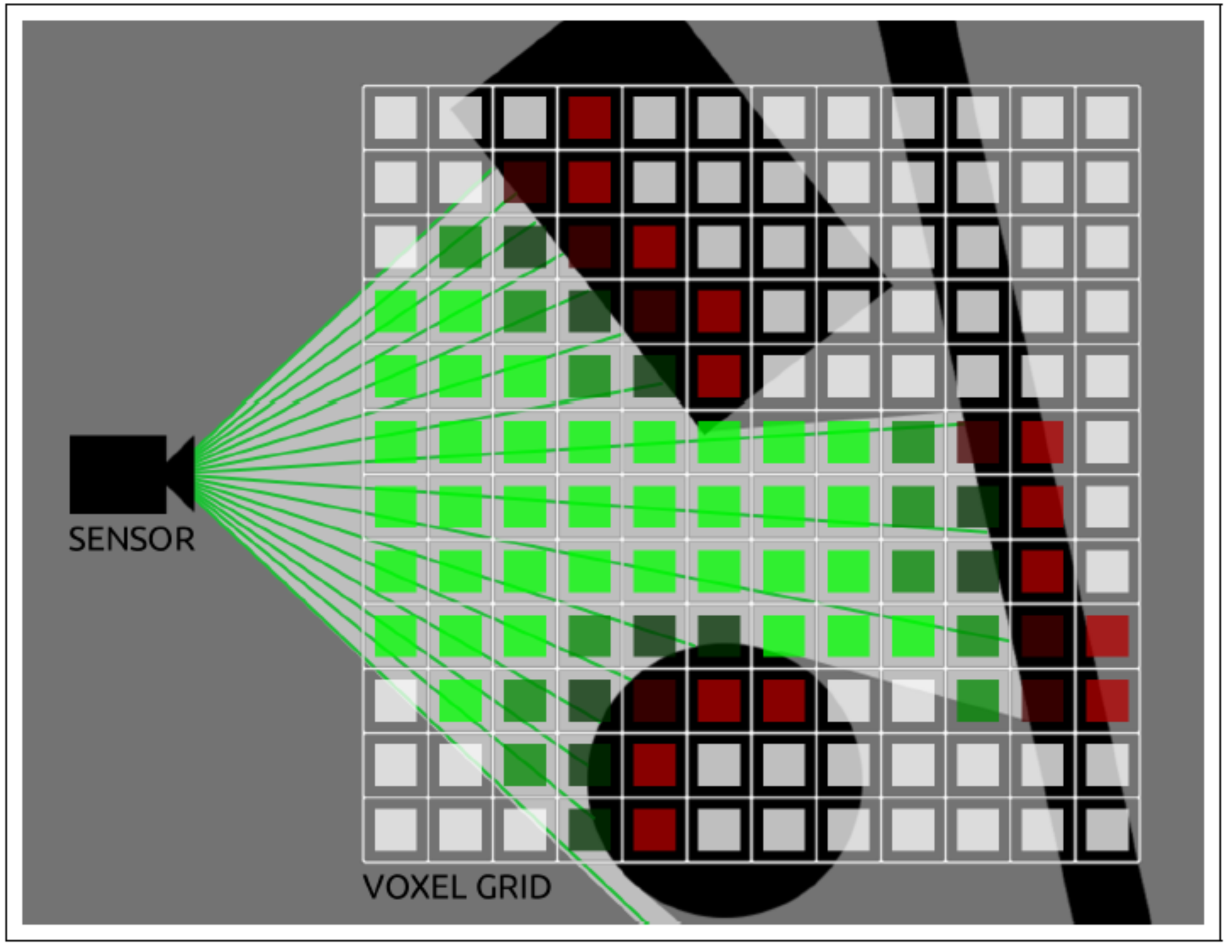
SDF and Truncated SDF

- Given the pose of the current camera R, t-
  - find the local coordinates by -

$$\mathrm{p}_w = R_t \cdot \begin{pmatrix} (x - c_x)\frac{\mathcal{Z}_t(x,y)}{f_x} \\ (y - c_y)\frac{\mathcal{Z}_t(x,y)}{f_y} \\ \mathcal{Z}_t(x,y) \end{pmatrix} + T_t$$

  - Obtain the projective point to-point distance as the difference of the depth of the voxel and the observed depth at $(i, j)^T$ i.e., $d(x) := z - Id(i, j)$

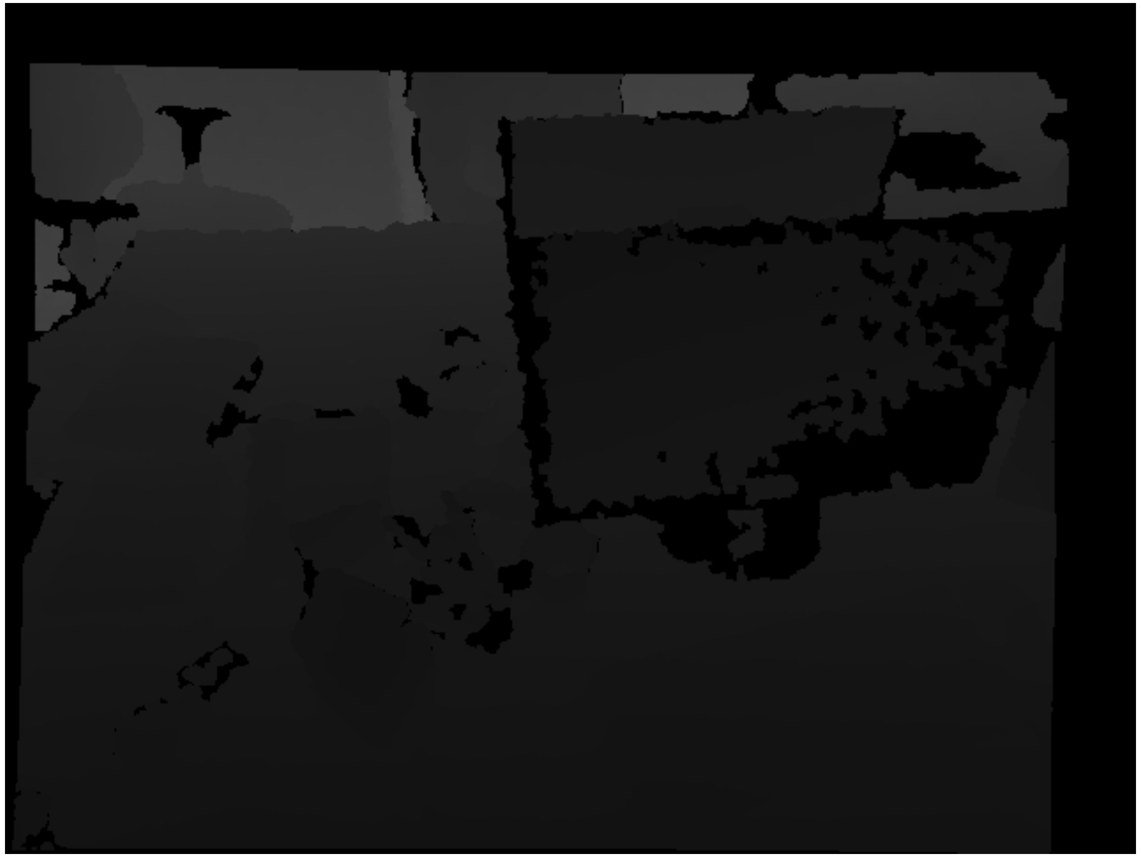
Illustration of TSDF



Results

Input Images

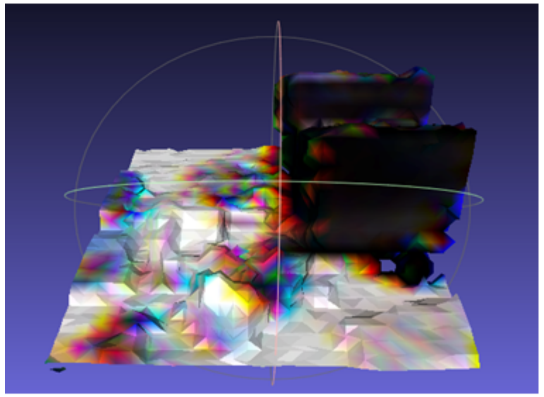
RGB Image



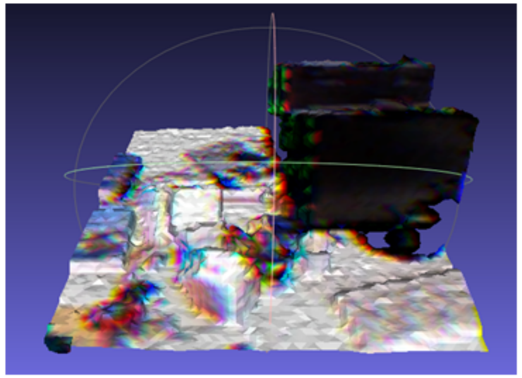
Depth Image

Reconstruction with Various Grid Dimension

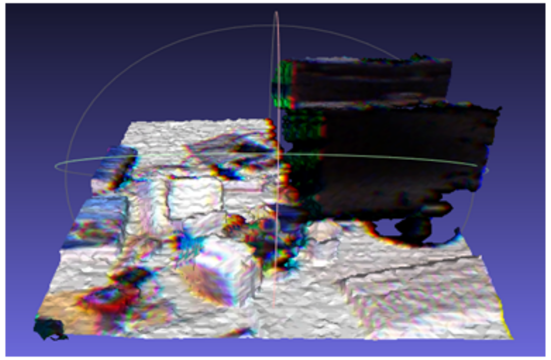
Grid Dimension = 32



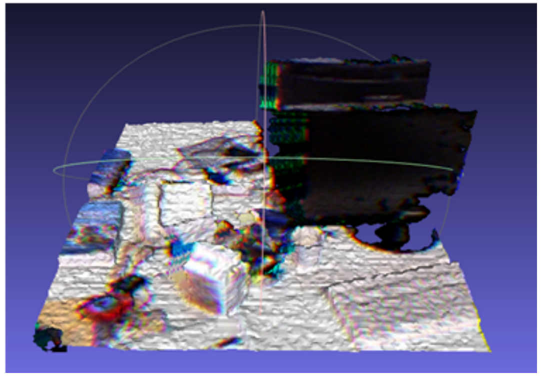
Grid Dimension= 64



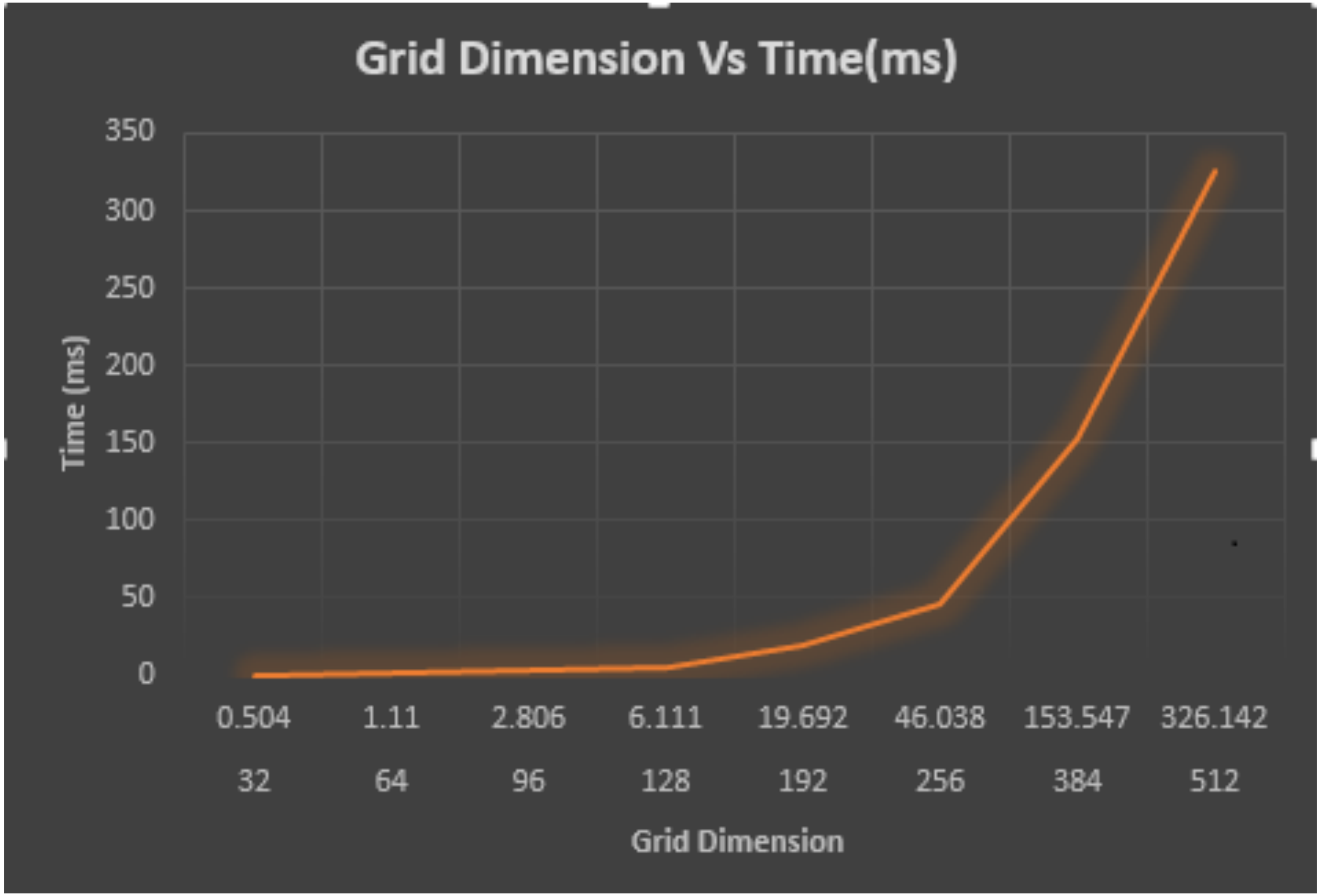
Grid Dimension= 96



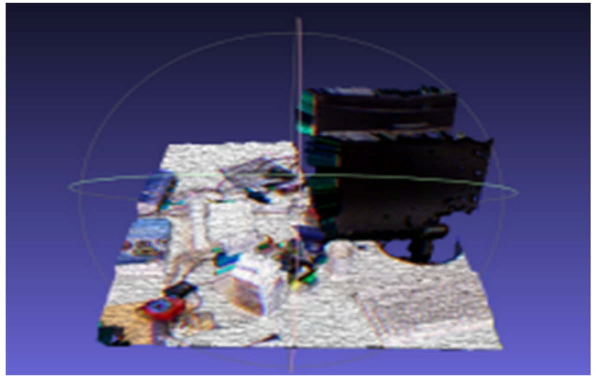
Grid Dimension= 126



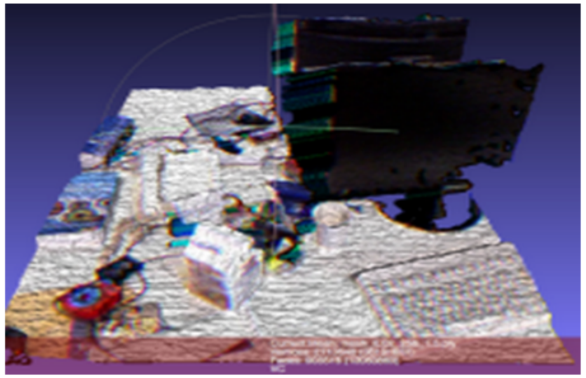
Computation time for various grid dimensions



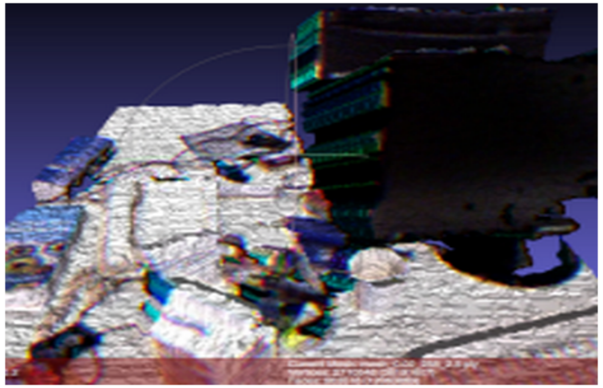
Reconstruction with Various Volume Size



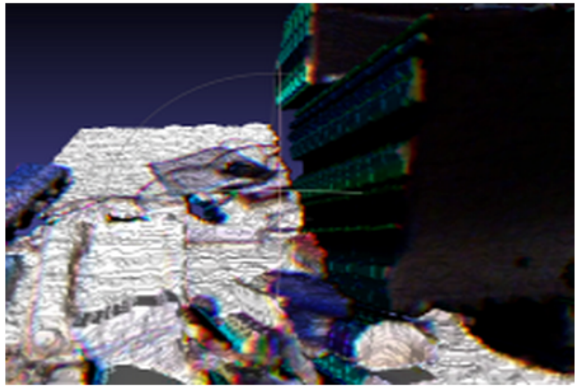
VS = 1.0



VS = 1.5



VS = 2.0



VS = 2.5

Live Demo