ABSTRACT

This paper presents a novel three-dimensional shape acquisition and reconstruction method based on the well-known Archimedes equality between fluid displacement and the submerged volume. By repeatedly dipping a shape in liquid in different orientations and measuring its volume displacement, we generate the dip transform: a novel volumetric shape representation that characterizes the object’s surface. The key feature of our method is that it employs fluid displacements as the shape sensor. Unlike optical sensors, the liquid has no line-of-sight requirements, it penetrates cavities and hidden parts of the object, as well as transparent and glossy materials, thus bypassing all visibility and optical limitations of conventional scanning devices. Our new scanning approach is implemented using a dipping and rotating mechanism and a beaker of water, via which it measures the water elevation. We show results of reconstructing complex 3D shapes and evaluate the quality of the reconstruction with respect to the number of dips.

INTRODUCTION

3D shape acquisition and reconstruction methods are based on optical devices, most commonly laser scanners, that sample the visible shape surface. ese scanners yield point clouds which are often noisy and incomplete. Many techniques have been developed to amend such point clouds, denoise them, and complete their missing parts using various priors [Berger et al. 2014]. All these surface based reconstruction techniques assume a reasonable sampling rate of the surface. Notably, these techniques fall short in cases where the shapes contain highly occluded parts that are inaccessible to the scanner’s line-of-sight. cannot be properly acquired nor reconstructed based on conventional (optical) scanners. Moreover, some objects are made of glossy or transparent materials, which pose another challenge that common optics cannot deal with. In this work, we take a completely different approach to shape reconstruction. The idea is to cast surface reconstruction into a volumetric problem. Our technique is based on the ancient fluid displacement discovery made by Archimedes, stating that: the volume of fluid displaced is equal to the volume of the part that was submerged. By dipping an object in liquid along an axis, we can measure the displacement of the liquid volume displacement and transform it into a series of thin volume slices of the shape along the dipping axis. By repeatedly dipping the object in various orientations we generate different volumetric displacements and transform them into what we call a “dip transform”.

3D reconstruction proceeds by measuring the volumes of oblique thin slices of the shape. We refer to the volumes of these slices as samples, and collect such samples along different angles. This, in turn, equips us with the ability to generate enough data to recover the geometry of the input shape. Since our technique is based on using volume samples that are generated by liquid accessing the object, we can acquire occluded and inaccessible parts in a relatively straightforward fashion.

LITERATURE

e problem of surface reconstruction from scanned points has been researched extensively in the last couple of decades. Nevertheless scan based acquisition and reconstruction are beyond the scope of this work, see e.g. [Berger et al. 2014] for a comprehensive survey. Computed tomography (CT) is the process of reconstructing an unknown volume from a collection of two-dimensional projections (shadow images) corresponding to different positions of the electromagnetic radiation source and representing the integral of emissions or absorptions from a given view. A classical way of reconstructing volume densities from line integrals captured by the projection images is via the Fourier Slice Theorem [Bracewell 1956; Kak and Slaney 2001; Radon 1917], which states that the volume densities can be recovered from a number of 1D inverse Fourier transforms of lines in the projection images. Alternatively, Algebraic Reconstruction Techniques (ART) iteratively solve a set of linear equations [Gordon et al. 1970; Kak and Slaney 2001] for the volume densities, using the Kaczmarz iterative scheme. CT plays a central role in medical imaging as well as in many computer graphics related applications. Trifonov et al. [2006] use visible light tomography to acquire objects made of glass and other transparent media. Specically, they measure the refraction of light through the transparent object and use tomographic reconstruction to reconstruct the object’s volume. Still, 3D reconstruction of transparent and specular objects has been a challenging problem in computer vision and graphics. Transparent and specular objects, may have complex interior and exterior structures that can reflect and refract light in complex ways. Since it is beyond the scope of this paper, we refer to the state-of-the-art survey of this eld [Ihrke et al. 2010]. Stochastic tomography has been introduced in [Gregson et al. 2012] for the purpose of capturing turbulent fluid mixing behavior. Instead of using the Radon transform (Fourier slice theorem) or algebraic reconstruction techniques (ART), their method uses random walks to reconstruct the volume from an array of cameras. Zhao et al. [2011] use an X-ray CT system to capture the inner structure of fabrics and model their appearance. To accurately render a material, a CT scan is used to capture its inner volume which is then used to compute the material’s scattering properties. Recently, Ijiri et al. [2014] use an X-ray CT system to accurately capture the intricate internal structures of real-world 3D owers. ey segment the volume into flower organs and apply active contours to smoothly reconstruct their surface

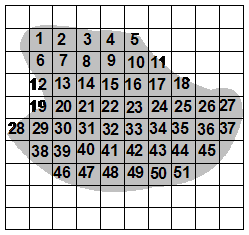
Moreover, New research has identified a novel way of 3D scanning objects by submerging them in water. The research team consists of authors from across the globe, from Tel-Aviv University, Shandong University, [University of British Columbia](https://3dprintingindustry.com/news/ubc-researchers-3d-print-sensors-revolutionize-water-industry-118619/) and Ben-Gurion University.

The team will present their work at SIGGRAPH 2017, the annual computer graphics conference. Joining them will be the Austrian team that created [novel 3D printing software for functional objects](https://3dprintingindustry.com/news/new-3d-printing-software-designing-functional-mechanical-objects-116853/).

DESCRIPTION

VOLUME MATRIX

We define volume matrix ‘V’ as a 2D “n\*n” binary matrix which corresponds to the 2D grid of prismatic object such that its element has either a value 0 or 1. So ,for the object shown in the figure below,The numbered element in the grid will have value 1 elsewhere its 0.



We now worked to design a mechanism that can dip the object into the water by 1 mm each time and will also rotate the object with an angle.

WEIGHTAGE MATRIX

This is the matrix that defines that how much part of each box of the grid assumed around the object is inside water.Let say when it is dipped 1st time into the water with an angle of 0 degree,each box in the bottom row will go into the water and hence the weightage matrix will denote such that its bottom row is all 1.But, for different angles,the scenario will be different. However,we succeded in devising the weightage matrix corresponding to each angle provided.

DIPPING TECHNIQUE and MEASURING WATER LEVEL

With the help of our designed mechanism we aim at following processes:

1. Fixing the object at 0 degree angle.

2. Dipping the object by 1mm.

3. Noting the change in water level in the beaker.

4. Again, dipping the object 1mm and repeat the same procedure until the whole object is diiped.

5. Now rotate the object with a certain angle and repeat the whole experiment.

SOLVING THE EQUATION

In the course of dipping the object, we obtained several data relating water level displacement and weight of the part of the object dipped inside,which can be formulated in way like

a1\*x1+a2\*x2+a3\*x3+….....+an\*xn = D1

Where a1,a2... are the value of each element of the weightage matrix and x1,x2... are the value of element of each Volume matrix that is either 0 or 1 depending upon the shape of the object.

Our main aim is to solve the above equation a similar sets of equation to find the value of x1,x2,x3..and so on which will give us the shape of the object.

These sets of equation can be solved using MATLAB and we will we working upon solving these in near future.

CONCLUSION

The paper presents a novel three-dimensional prismatic shape acquisition and reconstruction method based on the well-known Archimedes equality between fluid displacement and the submerged volume. A strong feature of our method is that it relies on fluid displacement as the fundamental shape sensor. The liquid has no line-of-sight requirements, which is advantageous compared to optical sensors. Furthermore, our technique allows for seamless penetration into cavities and hidden parts of the object as well as transparent and glossy materials, thus bypassing all visibility and optical limitations of conventional scanning devices. Our results demonstrate the capability of acquisition and reconstruction for a wide range of shapes with large occlusions and hidden regions.

One obvious limitation of the proposed method is its speed of acquisition. The mechanical arm dips the object vertically step by step, and it is necessary to read the liquid level in between steps, which introduces a temporal bottleneck.

Further,our future work aims at reconstructing a complex 3D objects and also aims at improving the technique for the measurement of increase in water level during dipping.