# Voxel Printing using Procedural Art-Directable Technologies

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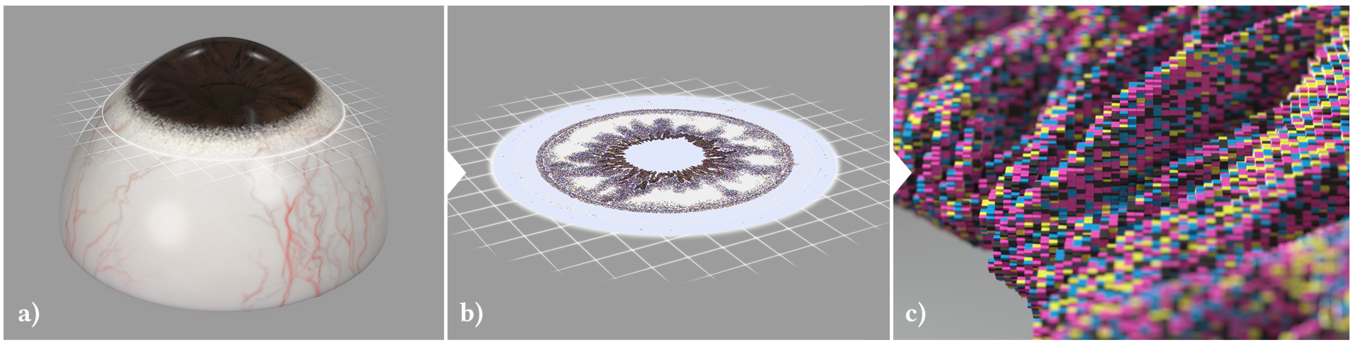


**Figure 1: a) The digital model is sampled by a slicing grid. b) Slice 650 of 992 images generated for a 2:1 eyeball. c) Visualisation of the voxels in a small section of the iris.**

## ABSTRACT

A procedural art-directable workflow is developed for voxel 3D printing using existing digital effects technologies. Customised for the Stratasys J750's unique materials, the system produces large-scale prosthetic eyes as a case study for film and display work.

## CCS CONCEPTS

• **Computing methodologies → Volumetric models**.

## KEYWORDS

3d printing, voxel printing, colour 3d printing, prosthetic eyes, additive manufacturing, hyper-realism

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## 1 INTRODUCTION

Traditional methods surrounding the manufacture of highly detailed organic parts can be advanced through the adoption of new complex 3D printing technologies. Stratasys' J750 3D printer uses a multi-colour and multi-material voxel based method that has the capability to achieve a new level of complexity not possible with other 3D printing technologies.

Voxel printing is unique in that the slice files that generated for printing contain a significantly higher level of fidelity than most current types of 3D printing. Each pixel in the image corresponds to a droplet of printing material. For coloured transparent prints, the 6-material printer is loaded with the photopolymer Vero materials Cyan, Magenta, Yellow, White, Black and Clear. Consequently, the image slices must only contain the colours corresponding to these materials. To achieve a full spectrum of colour, these 6 materials must be mixed together through quantized dithering. Currently, there are no 3D modelling programs that exist with the integrated capability to create and control this amount of data, then generate the output files.

While there has been previous research into the J750, particularly MIT's prolific science-based work [Bader et al. 2018], and Cuttlefish's colour management algorithms [Brunton et al. 2018], this work does not meet the level of creative control we require.

## 2 APPROACH

In order to generate such a high amount of data (over 10 million points of voxel data is needed for a $1cm^3$ cube), we turned to the software Houdini [Side Effects Software Inc. 2019]. Predominantly used by the visual effects industry, it has the capacity to process and handle the large amounts of information needed for voxel printing. The software's procedural node-based workflow makes it possible to create a reusable system of changeable parameters. Anything made in or outside Houdini can be sampled, meaning those with more expertise in other programs can still work with the Houdini specialist to convert their designs into a voxel print.


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Our current method for the core voxel printing workflow now involves an animated grid which samples data from any model as it intersects through it. The most success was found through point attribute transferral, however sampling directly from volumes has use in some data-heavy cases, based on the level of control required. Once this data is gathered, a custom quantized dithering algorithm converts RGB data into the mix of materials required by the printer [W. Floyd and Steinberg 1976]. Automating the process in Houdini enables the designer to view the code at various levels of complexity, depending on their level of skill with the software.

Previous methods involve limited editing of information, whereas Houdini is designed to manipulate data. Using Houdini to manage the data needed for voxel printing means we gain complete control over the output, and can alter that output accordingly to specific art direction.

**Figure 2: The final 2:1 eyeball 3D print, ready for display use in hyper-realistic large-scale human figures.**

## 3 APPLICATION

Weta Workshops traditional method for creating prosthetic eyeballs was effective, but had a high failure rate and had to be standardised. The voxel printing process allows us to create customised eyeballs at varying scales per-character. Aspects like the iris and sclera colour, limbus transparency and vein weight can be controlled in an artistic manner.

Traditionally at Weta Workshop, prosthetic eyes were produced through a modelling, multi-stage casting and painting pipeline which was limited by the constraints of the method and materials. Conversely, the voxel printed eyeballs replicate the level of translucency and complexity found in a real eyeball, unrestricted by the limitations of traditional manufacturing. Notably, despite the inherent refractive index difference between the synthetic and organic materials, light appears to refract onto the iris in the same way. This is due to the level of dimensionality in the eye, including the level of synthesis possible between opaque and transparent areas of the print. While there will always be opportunity to improve the reproduction from an anatomical point of view, for the purpose of film and display use, these 3D prints easily meet our expectations for believability and character.

Future work will be completed on improving colour reproduction, proofing the print before processing and general optimisations to the method. Currently the method's colour proofing relies on physically printing test samples, however Houdini is entirely capable of allowing us to further refine the digital pipeline. Furthermore, due to the nature of the transparent coloured materials, subtractive colour mixing occurs when these materials are layered. This makes it difficult to accurately render "print previews" which predict the final appearance of the colour and its interaction with the opaque white material. And finally, now that a controllable method of voxel printing is effective, the integration of soft and flexible 3D printable materials can also be studied to identify new approaches for designing for soft, organic parts.

The choice of prosthetic eyeballs as a case study necessitated a high level of control over the production of believable organic 3D prints. It is now possible to use these new methodologies as a foundation to expand into full characters and other objects conducive to Weta Workshop's work.

**Figure 3: A selection of 3D printed prosthetic eyes at varying scales and colours.**

## ACKNOWLEDGMENTS

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