The perception of fluid properties and how it influences an artistic direction in 3D printing

Dominique Claire Matthew and Oleg Fryazinov

The National Centre for Computer Animation, Bournemouth University, UK

Abstract

In this work we explore this fusion of art and technology through the 3D printing of fluid simulations and what limits the design of such simulations before perception is abstracted. The challenge of 3D printing complex forms presents itself through the comparison of the artefacts and what was rendered online. The properties of fluid are controlled using viscosity, speed and collision objects and a static frame of the simulation is 3D printed. This paper presents the potential pipeline to 3D printing of fluids and the process undergone to achieve aesthetically pleasing results.

Introduction

3D printing is a subject that is now entwined in the extensive areas of life. From medicine to industrial applications, this form of manufacturing has aided design and advancement from the stages of prototypes to the final output. This method became embedded within the art community as a new way to creating forms that would otherwise be extremely difficult or almost impossible. Artists can now create physical forms without having to restart processes from scratch when they wish to go back a step or edit a piece as the 3D model is saved on 3D software; thus, providing the creative freedom of unlimited iterations.

In this work we explore the artistic side of fluids, engaging in the 3D printing of computer-generated fluid, and the limitations that affect our perception of what makes a 'fluid form'. We present a range of sculptures that demonstrate fluid motion in abstract ways whilst also retaining the visual properties that make the fluid recognisable as one. The reason behind the interest of printing fluid simulations from 3D software came from wanting to push the boundaries of printing thin meshes before the printer found it difficult to proceed with the formation of them. This interest echoes from 3D printing being described as having an unlimited range of possibility of what can be produced, even with complex designs.

This paper presents the potential pipeline to 3D printing of fluids and the process undergone to achieve aesthetically pleasing results. This pipeline can be used by creators with 3D software and 3D printing hardware to create intricate freeze-frame forms of fluid with the only restriction being the (lack of) thickness of the mesh.

Related works

Fluid-shaped or fluid-inspired artworks existed for some time yet being quite rare because of the way of producing it. For example, the artist Aylin Bilgiç creates porcelain bowls [1] with gold-accented droplets (Regus, 2017). Annaluigia (Annalù) Boeretto uses resin-glass to create her 2012 sculpture Un Salto Nel Blu [2] of which takes on average 24 hours to reach 95% of its full cure. Artists such as Boeretto and Bilgiç have more control with the overall look of their sculptures as they are handmade, unlike Jack Long, a fluid photography artist, who creates intricate fountains containing various colours of liquids [3]. Eyal Gever, a contemporary artist with a passion for tech-art, has created a two-metre sized Waterfall 3D print [4], which captures the essence of a destructive force of nature. The main inspiration for this work came from Fung Kwok Pan's Fluid Vase [5], an interactive 3D printed ceramic piece where the customer can alter the height of the fluid being poured, the container shape as well as when they want to pause the simulation, and hereby this artist avoids the act of randomness.

Method overview

Sculpting of fluid-like shapes is not a trivial process which in our method was separated into several steps. On the first step the fluid was simulated in specialised software such that the overall shape follows the artist's aesthetics. On the second step the simulation is converted into the shape representing 3D solid model and on the last one the model was fabricated by using 3D printing to assess the resulting sculpture. Artistic direction was important on every step of the process as we are discussing below.

In this work the RealFlow software was used to simulate the fluid. The software allows changing a wide range of parameters in order to get the desired shape. The artistic control was implemented with taking parameters such as viscosity, pressure/velocity fields and simulation ratio into an account.

The main parameter which controls the shape of the sculpture is viscosity. As it was noted in [6], observers ordered their judgements of liquids based on their variation in viscosity and when the liquid behaved differently from being poured, viscosity deviation was still obvious.

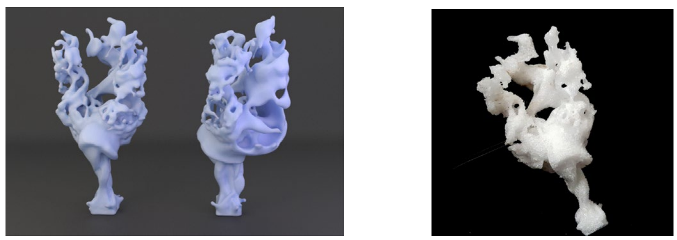
Figure 1: *D-Spline meshes with viscosities/speed: 100 Pa.s / 10m/s, 50 Pa.s / 1m/s and 3 Pa.s / 1m/s.*

The early experiments show that constant viscosity, especially of high value, turned out to be of a little artist control and resulted in undesirable shape. It was noted that as the viscosity increased, there was a significant decrease of the volume in the main component of the shape, which was noticeable when the extra components were removed (Figure 1). In our work the viscosity was further controlled by splines that follow the flow of the simulated fluid and allow to be modified by the artist. In the RealFlow software this was implemented with so-called D-Splines. The decision to use splines was inspired by the works of David Lund, in particular "Liquid Gold" [7], of which the fluid appeared to be controlled by other forces rather than gravity. Unlike simulating fluid through pouring, specifically those with high viscosities, using splines allows more creative flow and unique contours due to the controllers of the vortex strength, axel strength and the radial strength. Variations in the speed of the D-Spline which allowed more particles to flow through at a greater rate, despite the increase of viscosity of which increases the difficulty when determining the velocity distribution. As a result, we were able to find the balance between lower viscosity areas that allowed to achieve a more visually aesthetic form that has depth and tone due to the holes in the mesh due to the free-flowing particles and higher viscosity areas that resulted in thinner shapes with high number of disjoined components.

Variation of parameters on the splines allowed also to control the shape by using modifications in the velocity fields. D-Splines also contained some vortex parameters that affected the rotational force of the fluid (Figure 3c). When viscosity was introduced into velocity field simulations, the form began to abstract and take on coral-like formations (Figure 3c), similar to Noiterksa [8].

The shape of the fluid simulation was controlled by using collision objects and varying the number of simulated frames. In the early experiments the fluid simulation of a box-shape object was interrupted after 3-5 frames and the collision object was added after that as an extra boundary condition that allowed to get the fluid-like appearance due to the ripples and ridges created that acted similar to a heightfield to represent a 2D shallow water equation [10]. Further control on the shape of the fluid was achieved by using additional external and internal pressure fields. External pressure fields allowed to dynamically change the form of the fluids, adding the visual cues of heightfields as well as overhangs and droplets on the surface. Internal pressure field was more difficult to implement, but with extra particles emitting from the fluid some variations were allowed.

For some shapes the result of the fluid simulation itself was not sufficient enough and further modification of the shape was required. The resulting "amalgamation" process, which was inspired by Kevin Mack's [9] and Alberto Seveso's works [11], was achieved by further sculpting based on simulated shape. In our work (Figure 2) the shapes from the fluid simulation were converted into the mesh object and then merged and combined in ZBrush software. The result still captures the perception of fluid and its properties yet having its own unique free-flowing final form.



(a) (b)

Figure 2: *Amalgamation: (a) render, formed by combining two previously created fluid meshes, (b) The 3D print, some parts of the resulting object were too thin and broke due to the fragility.*

One drawback of the fluid simulation is that the resulting shape can have several disjoined components which cannot be 3D-printed as a single object. In this work we had to remove extra components leaving only the main one. Occasionally this would have an impact on the aesthetic of the piece, although, to combat this, the entirety of the mesh could then be taken into the sculpting software and the simulation could be conjoined manually which would alter the perception of said fluid.

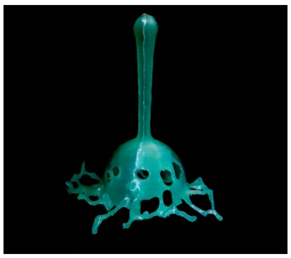
Majority of the 3D prints were fabricated as solids with translucent plastic, i.e. the infill was set to 100% providing a smoother and more visually appealing finish. Translucent material made it look more like a fluid whereas non-translucent materials felt and looked artificial even if the colours of water blue-green palette was used. As majority of the prints required support structure, the support was added either of the same material as the mesh to be printed or soluble support material which helped with the construction of the shapes.

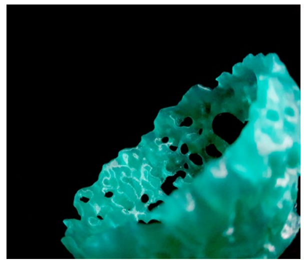
Results

The process of getting the final sculpture in our work was formalised into the following pipeline:

1) Set up parameters for the simulation and simulate fluid;
2) Export the mesh object from fluid simulation;
3) If needed, adjust the resulting mesh in the sculpting software;
4) Run component analysis on the mesh object and remove all the components except of the main one, i.e. the one with the largest volume;
5) Send the one-component mesh object into the slicing software and 3D print the object.
6) Clean up the resulting 3D printed object from the support material.

The results show that the pipeline proved to be a successful way to create fluid-like shapes. The pipeline worked in sync with the software used with mathematical calculations of fluid happening at the start of the process and visualisation happening at the end. The Ultimaker was successful with printing small yet complex designs, particularly those that had features with a high chance of breaking within the structure during creation such as the Amalgamation piece (Figure 2). Some of these prints required to be printed multiple times specifically the external-force test that was printed with and without support (Figure 3b). At the same time the drawbacks of low-budget 3D printers were apparent during digital fabrication process. Although soluble support material was used, the resulting object sometimes was too fragile which resulted in unsuccessful 3D printed object. Moreover, for some objects, soluble support material was even more destructive than helpful due to the weight of the support material as it was dissolving on the fragile parts of the tendrils.


(a)


(b)

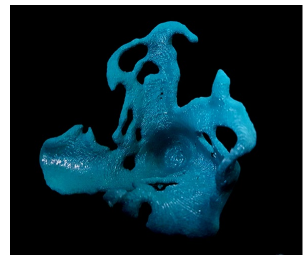

(c)

Figure 3: *Results: a) The Initial-Fluid print, b) External-Force print. c) High-viscosity Vortex print*

Summary and Conclusions

This paper presents an insight into the process of using 3D printing to create a fluid-like sculptures. This project aimed to establish the pipeline and justify the idea rather than create an artefact for exhibition.

This project has many aspects which were not properly explored in detail. For example, the choice of materials was limited to types of plastics supported by 3D printer we used. For more detailed investigation it would be useful to take a look at other materials such as metals, ceramics and resin. Also the scale of the resulting prints in this work was relatively small, with the average size being 60mm x 45mm x 50mm, while sculptures of professional artists tend to be a lot larger. In order to get a larger scale, the design should be planned more carefully.

The artistic direction of printing fluids is still limited due to the issues there are with printing thin meshes as well as the difficulty of having complex and entwining structures. We hope one day 3D printing will offer an unlimited choice of what can be printed. Ultimately, the scope as to what can be perceived as a fluid is unlimited as, even when abstracted, there are properties that present visual cues of that help to determine the sculpture as being a fluid.

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