Space-Time Cubification of Artistic Shapes

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Figure 1: *From left to right: 4D Cubist Camera projection of articulated human figure with space-time blending between time instances; Cubification of articulated human figure; Cubification of articulated human figure with 4D Cubist camera projection; 3D Cubist camera projection with artistic effects of cubified articulated human figure.*

ABSTRACT

This poster describes an original approach to creating and producing artistic shapes in a cubist style. We propose mathematical models and algorithms of adding cubist features to (or cubification of) time-variant sculptural shapes as well as a practical technological pipeline embracing all the main phases of their production. A novel method is proposed for faceting and local distortion of the given artistic shape. A new concept of a 4D cubist camera is introduced for multiple projections from 4D space-time to 3D space and combining them using space-time blending to create animated sculptures. 3D printing for stop-motion animation is considered as one of the final pipeline processing stages. The proposed techniques are implemented with artist friendly user interfaces and experimental results are presented.

CCS CONCEPTS

• **Computing methodologies** → **Computer graphics**; *Procedural animation*; Shape analysis;

KEYWORDS

Hybrid Representation, Space-Time Blending, Cubism, 3D Printing

1 INTRODUCTION

Dynamic sculptures created with help of computer-aided design and animation tools and related to a proper artistic style and tradition within a particular artistic movement are surprisingly rare. Of

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course, there are well-established methods and tools allowing for modelling, rendering and animation of an almost infinite variety of shapes. There are also some powerful design tools for sculpturing static shapes [Séquin 2005]. However, creating dynamic art shapes are mostly concerned with traditional engineering and manufacturing practices. In this project we consider an original approach to creating artistic shapes related to the cubism movement.

This project has also served as inspiration for some original theoretical concepts integrating modelling and animation in the context of multidimensional conceptual space. There are parallels between cubism and 4D space, nD space and non-Euclidian geometries [Robbin 2006] which have influenced the project.

2 OUR APPROACH

2.1 Overview

Cubist painters moved away from traditional methods of projecting a 3D scene onto a 2D canvas, instead experimenting with using multiple viewpoints in a single composition. We propose to look at the theme of taking an n dimensional object or scene and reducing it to an n-1 dimensional representation through the new concept of a 4D cubist camera, which, by analogy with the well-established 3D cubist camera [Glassner 2004], is projecting two or more instances of a time-variant shape from 4D space-time to 3D space at the given time moment with possible preliminary blending between these instances. Whilst the 3D cubist camera [Arpa et al. 2012] deals with just rendering, this novel 4D cubist camera realises integration of modelling and animation phases through blending (i.e. compressing) a few frames generated on the basis of a faceted model with attached time-variant transformations into one thus producing cubist effect.

We propose a general shape model and develop algorithms to implement all the distinctive features of cubist sculptures. Then, provide a combination of the tools into a single system with artist's interactive or procedural control. All components of the shape model have to be time dependent to support a sculpture changing in time. We will use a hybrid representation combining polygonal
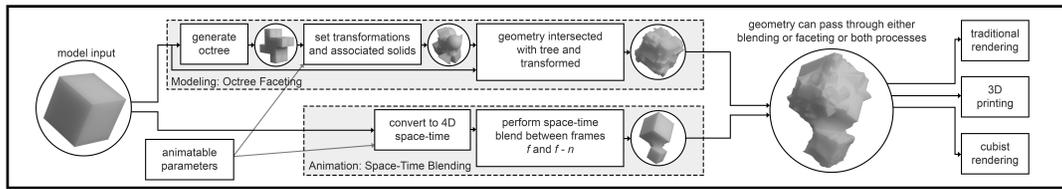
Figure 2: *Cubification and animation production pipeline.*

meshes with signed distance fields (SDFs). We will cover all the steps through the full production pipeline from data acquisition, to shape modelling, animation, rendering and 3D printing (Fig. 2).

2.2 Shape Faceting
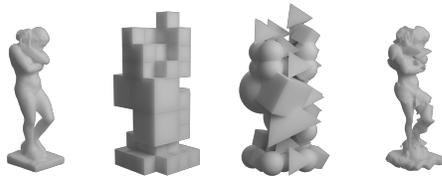
Figure 3: *Steps of faceting the given sculpture from left to right: initial shape (scanned model, Three D Scans); corresponding octree; associated primitive solids; rotated and scaled facets combined with manipulated initial mesh.*

Cubification of an artistic 3D shape is based on faceting using adaptive subdivision into solid pieces (facets). Octree-based subdivision is used as it provides a loose form of feature sensitivity. Shapes and transformations are then associated with each of the leaf nodes in the resulting tree structure. Each of the shapes are then intersected with the original shape and transformed using their associated transformation. The resulting facets are then combined with the initial mesh to produce the final result (Fig. 3). The transformations associated with each facet can be animated by the artist to produce dynamic sculptures.

2.3 4D Cubist Camera

Figure 4: *Space-time blending applied to non-adjacent instances of a rotating and oscillating cube.*

We employ space-time blending [Pasko et al. 2004] for combining (or compressing) several shape instances (frames) into a single shape. Note that in this process animation is considered as modelling in 4D with projections to 3D. Another aim of using space-time blending was to generate motion trails to follow the

facets produced by the octree method described earlier. To achieve this, instead of blending between two separate objects, the blend is performed between non-adjacent shape instances (frames) t and $t - n$. This allows for the effects of the surrounding frames of an animation to influence the current frame being viewed, producing a cubist-type projection of 4D space-time onto 3D space (see fig. 1 and fig. 4).

2.4 Implementation and Experiments

Houdini was a natural choice as the host application for the tools developed in this work. The implemented techniques rely heavily on the use of sparse volumes (discretised SDFs) from the OpenVDB library developed by DreamWorks Animation.

Figure 5: *Left to right: 3D printed results showing faceted statue; a faceted mug from 3D scan data; a faceted articulated human rendered with a 3D cubist camera.*

3 CONCLUSION

We have proposed an original approach to adaptive cubification of existing sculpture models including faceting and local distortions. A new concept of a 4D cubist camera as a projection method from 4D to 3D space was introduced. A pipeline embracing all the phases of artistic production from data acquisition, to shape modelling, animation, rendering and 3D printing has been realised. Some artefacts produced during this project can be seen in Fig. 5, the supplementary video and images.

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