Abstract. Gaming and visualisation software has a history of developing economical and creative methods to deal with hardware limitations. Traditionally the visual representation of gaming has been a poor offspring of high-end architectural visualisation. In a twist of irony, the paper proposes that game production software leads the way into a new era of physical digital ornament. The toolbox of the rendering engine evolved rapidly between 1974-85 and it is still today 20 years later the main component of all visualisation programs. The development of the bump map is of particular interest; its evolution into a physical displacement map provides untold opportunities in the appropriation of the 2D image to a physical artifact. Contemporary Architects in tandem have been mapping to the façade a new era of complex three-dimensional sculptural representation. The Architect, Designer and Artist now have the opportunity to appropriate the image map and use advanced visualisation technologies in the application of digital ornament.

Introduction

Gaming and CAD visualisation software share a diversity of program usage, each area has its selective methodology on which parts of a program it adopts, a particular modeling tool, a rendering capability or its animation capabilities. Software providers have provided provisions for all areas of production and this has in turn has promoted an eclectic overlap. Advances in gaming resolution will figure heavily in the forthcoming years, leading software provision into a sophisticated dialogue of increased topology. Historically decoration disappeared from the early modern designer’s lexicon; today advanced modeling and CNC technologies will allow ornament back onto the center stage.

The appropriation of the visual 2D representation into a 3D artifact is the aim of the research, to explore and highlight the possibilities available. With such a large resource of 2D maps produced the possibilities are endless - always a positive thing for creativity. The basic toolbox of the render engine is not an exclusive CAD visual element; it appears in many genres of virtual representation, employed differently per incarnation.

Texture Maps

Today the texture map is far from being just a mere image based activity; it has evolved into a powerful tool for the geometric displacement of topology.

Why texture map? In the quest for more realistic imagery, one of the most frequent criticisms of early-synthesized raster images was the extreme
smoothness of surfaces – they showed no texture, bumps, scratches, dirt or fingerprints. Realism demands complexity, or at least the appearance of complexity. Texture mapping is a relatively efficient means to create the appearance of complexity without the tedium of modeling and rendering every 3D detail. (P. Heckbert. 1986).

Over a short 10-year period the major components of today’s rendering software environment were formed. Between 1974 and 1985 texture mapping evolved from being a singular method of mapping colour onto a 3D object, to a multitude of user-defined attributes.


Figure 1. From left to right the application of a colour map to a sphere

BUMP MAP EVOLUTION

Jim Blinn's paper "Simulation of Wrinkled Surfaces" published in 1978 is an iconic paper documenting his research [invention] into the making of what is widely known now as a bump map. It signaled for the first time a progressive movement towards the appearance of true complexity and realism in the CAD environment. Pre 1978 visualisation and gaming had lived in a flat raster based world.

Blinn employed a technique that mapped a grayscale 2D image to the surface of the 3D object. The grayscale map is employed with a lighting module to determine the height of the image-based displacement. The white end of the grayscale determined the height of the displacement and the arrangement and the graduation of the source image file determined the overall effect of the displaced surface. In essence, the grayscale map became a height map to be used by the render engine in displacing the pixels in the image rather than displacing the geometry of the actual object.

DISPLACEMENT MAPPING

Displacement mapping is a further advancement in Blinn’s technique. It is directly related to bump mapping in that it also uses a height map to model surface perturbations. The difference, however, is that displacement mapping actually modifies the surface geometry, whereas bump mapping only affects the normal vectors. In other words, displacement mapping adds geometric detail to the mesh. (T. Nuydens 2004).

Polygon displacement can provide us with physical [virtual] surfaces of geometric complexity. It is true that the level of processing power along with the complexity of mesh need to gain a detailed object can be overwhelming, especially for animation and gaming. However, the evolution of the bump
map into displacement expresses the first beginnings of a process that automates the modeling of highly detailed objects; a process that does away with the tedium of having to model every little detail, conceptually it can provide unprecedented levels of detail.

DISPLACEMENT BAKING

Displacement baking is a term used to describe the conversion of a displacement map to polygon model. It bakes the image representation onto a 3D polygon model. Further research has located the appropriate program to extract an image based mesh displacement. Out of the traditional stable of programs 3D max, Form Z, 4D Studio, Rhino 3D and Maya [there are many others], Maya the animation and game-modeling program offered the most potential.

The ‘Displacement to Polygon’ feature gives you the ability to bake the displacement-map. The creation of a polygon model through image displacement is a powerful concept and offers interesting opportunities in the creation of complex digital models.

DEVELOPING DISPLACEMENT: TOP2MAYA, ZBRUSH

Further investigation into the process of displacement methodology unearthed a scientific appropriation of Maya’s Baking process. Rob Gillespie created an appropriation of the displacement feature in 2000; He harnessed the displacement-baking feature of Alias’ Maya for the visualization of cell structure. This was an interesting diversion of bump map technology; it was worlds apart from video gaming, children’s animation and architectural visualisation.

Top2maya is a program written in MEL script, which changes 2D topographical maps into three-dimensional models. (Rob Gillespie 2001)

Top2maya is largely still an image-based activity it relies on an accurate scientific formula to reproduce the closest possible representation of cell structure. Top2maya offers us the beginning of a tool that can translate, accurately image maps into displacement maps. It automates the process of image to displacement to polygon model very efficiently and is extremely user friendly, making it a suitable tool for the Architect or Designer who wishes to displace CAD geometry but has no advance knowledge of Maya.

![Figure 2. Top2Maya molecular displacement; Zbrush image: 2.26 million polygons mapped into 138 polygons](image)

The concept of baking as a process offers us a path into the physical construction of complex computer topology. Software products such as Z brush by Pixelogic, inc. deal specifically with the sculpting of high-
resolution models in real time. It does this by layering displacement and normal maps on top of what are, at first, low polygon constructions. The baking method allows consolidation of detail at each application of texture and it can build on the displacement process to create a complex displacement detail.

Another way that ZBrush can make use of ‘displacement maps’ is to actually convert the displacements into geometry. This allows you to recreate a high-resolution mesh from the displacement map. (Zbrush. Pixologic, inc)

The Architects Map / Displaced architecture

There is a common ground between contemporary architectural practices and displacement technology; both employ a map in the creation of form. The map employed within contemporary architecture is extremely varied; architectural inspiration can come from an image map, a specific painting, the microscopic imaging of biomorphic forms, to a scale of a country that has been digitally mapped through advanced topological surveys. The library of 2D data available to the architect is an expansive collection. The process of mapping follows a similar trait to that of game image production; the architectural design process transforms 2D imagery into the 3D architectural object.

Further, the façade is becoming an increasingly animated architectural asset; it is in a period of digital development. Similar to the development of the texture map, the façade has developed into a three dimensional language. The purpose of the research is to identify the relationship of these facets in order for architectural practice to understand that the displacement method is a viable method of architectural appropriation. The use of an image map to create 3D forms offers the architect, designer and artist an avenue of future topological development.

ARCHITECTURAL DEVELOPMENTS IN THE MAPPING OF SURFACE

Herzog and De Meuron’s work has evolved from early experiments in two-dimensional patterning. The practice has been rewriting the traditional perception of the building façade, introducing contemporary ornament back into modern architecture. In 1989-1993 Herzog de Meuron built The Pfaffenhof Sports Center in St Louis France and used a method of concrete printing to animate the façade, similar in process to that employed by the image map.

The longitude facades and the square in the front of it are covered in pre-fabricated concrete slabs whose surfaces have been roughened with a specially developed printing technique that makes them appear like photographic surfaces. (Jeffery Kipnis 2007)

The early work of Herzog and de Meuron referenced the two-dimensional character of textiles, they applied an image map to emboss and enhance a simple building substrate, concrete. A further development of process is evident in the rain screen panels in the De Young museum in San Francisco Completed in October 2005. It shows a development of the buildings surface
into a displaced, subtractive façade. The Beijing Olympic stadium due for completion in 2008 is evidence of an architectural development into a 3D structural solution, where façade becomes structure and structure becomes ornament. The work of Herzog de Meuron and their development from earlier 2D representations to the 3D physical has an uncanny association to the developments in bump mapping and the displaced model.

![Figure 3. Herzog de Meuron: Concrete print, rain screen, Beijing stadium](image1)

Caruso St John’s architectural practice has shown an interest in the return to historical ornament through digital appropriation of Lace. The process is an image-based displacement; simple in concept, it offers a high level of detail. A sample of lace is scanned, displaced and outputted as a 3D computer model, this then molded into the pigmented pre cast concrete panels forming the elevation of the center. Simple in its concept, the façade again has been animated into three dimensions and references historical precedents.

“We’re trying to start to express more formally the idea that interpretation is a very powerful thing. Interpretation of tradition has always been how you made art and architecture, ‘its only really since the 1950’s that this idea of pure invention intruded. And it’s only got silly in the last 20 years or so. If you make pure invention, how can it possibly have any density, compared with something that has hundreds or thousands of years feeding into it?’” (Caruso St John 2005)

Caruso St John Architects’ usage of digital displacement offers us another precedent as to how the application of digital topology can be intelligently developed in contemporary architecture. Their appropriation of the past and its interpretation through a digital process is an architectural intervention; as a means of architectural expression it shows a renewed interest in the revival of ornament. It feeds on the past rather than consigning history to the past and provides us with evidence of a philosophical move back to the use of highly detailed ornament.

![Figure 4. Lace Façade detail: Caruso St John, Nottingham Contemporary Art Centre, Malevich: White on White, Erick van Egeraat: Tower](image2)

Architects have often referenced art works as a design inspiration. EEA Architects, Erick Van Egeraat’s architectural practices commission for five residential towers in Moscow is one such reference.
The site in Moscow is located in the Yakimanka area, across from the New Tretyakov Museum, an institution that has one of the best collections of Russian Avant-Garde painting. Seizing on this fact, van Egeraat decided that each of the towers would refer to a specific painting. (Philip Jodidio 2004)

One of the paintings referenced was Kasimir Malevich’s white on white 1918. The Avant-Garde artwork exists as a two dimensional artifact, van Egeraat has used the architectural design process to displace the architectural facade. The tower inspired by Malevich’s white on white painting plays with the displaced monochrome topology of the painting; it is a similar approach to that of a grayscale map employed in the displacement process.

A New Age of Ornament?

The potential of displacement to object is a powerful and exciting expression of modern technology. The emphasis must also be placed on a desire to move forward away from the simplification of structure and form into one that deals with the real possibilities of expanding the dialogue of surface. A new age of ornament, that expresses contemporary practice and relates to modern practice.

Historically, a wonder of natural systems has served scientists and creative designers well. For example, Leonardo da Vinci's studies of anatomy and the botanical formed the basis for both his art and his interventions. This contrasts sharply with the first half of the 20th century when the motorised machine- became the model for architecture. (M. Weinstock., 2004).

Historically mankind has expressed technological advancements through the process of making. There are distinct periods in history that have left us a rich creative legacy of the development of mankind. The agricultural revolution, the industrial revolution, the machine age have all left us with architectural expressions of the time through the built form, along with a rich catalogue of artistic and sculptural artifacts. These artifacts clearly express the advances made within each distinct period and provide a rich source of historical inspiration for today’s designer and architect.

ARTISTIC AUTONOMY

Within the freedom and autonomy of art practice Tord Boontje is at the forefront of digital ornament. He produced a highly influential solo exhibition called Happy Ever After, held at the Moroso gallery, Milan 2004. The exhibition was also exhibited at the Moss gallery in New York 2005. His philosophical stance is aided by the autonomy of art practice and is a progressive move away from minimalism towards an unapologetic usage of contemporary ornament.

Boontje’s genius has been to tap into the sensory appeal of hand crafted historical ornament, but repackage it for the computer age, exploiting the latest high tech processes to produce domestic objects with a craft aesthetic at an affordable price. (L. Jackson. 2004)
In an interview with Josephine Minutillo in 2005, Tord Boontje expressed the issues surrounding the return of ornament. “The word decoration often has a negative connotation in Modern architecture and design. What are your thoughts?”

“Decoration is not a negative term for me. The original ideas behind Modernism got hijacked somehow and the term Modern has come to mean something that is very stylistic or minimal—something devoid of the original, important emotional qualities of Modernism. I try with my work to bring back sensuality and human qualities in the spaces in which we live and the objects with which we live and to do it in intelligent, efficient, and affordable ways. In a funny way, what I’m doing is very modern.” (L. Jackson, T. Boontje 2004)

Conclusion

The development of the bump map into the displacement model is a significant advancement in generation of detailed physical forms. The research into the evolution of the bump map identifies areas of appropriation that can be utilized by architecture and design, to aid the creation of complex digital displacements.

Rob Gillespie’s Top2maya provides a precedent to the implementation of a tool-based approach to the displacement feature within Maya. It is a user-friendly interface for the creation of complex polygon forms and is operable by CAD novices. Further development in topology may be sourced from programs such as Z Brush, its operational interface is not suited to the novice but it has incredibly powerful displacement features.

In architecture displacement of the façade is becoming an increasingly contemporary practice and it has many facets of inspiration. Herzog and de Mueron, Caruso St John and Erick Van Egeraat have followed a similar development of topology to that of gaming software. In the case of Herzog and de Mueron the path of development almost mirrors the development of the texture map.

It is not the intention of this research to focus on the ornament of the past; it focuses on today’s relationship of science and technology, it is to avoid the pastiche of the past. There is the desire to express an ornament that deals with today’s increased visual perception. Digital Ornament’s relationship with architecture is that it is able to create and form complex 3D topological data, referenced from a diverse catalogue of 2D maps; It is able to 3 dimensionalise this information.
As an indication of a method of fabrication, rapid prototyping and Computer Numeric Controlled CNC machinery is the link between the virtual mesh representation and the physical form. Architects have been using RP to fashion a new era in fluid design; CNC machineries are increasingly being used in the production of bespoke architectural elements. This gives us the first indications of how we might extract a map, texture or newfound topological data and bring it into the Architectural realm.

Further, it is natural that we want to expose our technology through art and architecture. Ornamentation is one way of expressing this. We have a better understand of our built environment than ever before, advanced digital mapping techniques now allow us to understand 3 Dimensionally the relationship of our environment and provides us with a new perception of our built environment. By consulting and interpreting this data through the displacement process there is the potential to have a new relationship with our landscape and built environment.

Digital Ornament is an expression of the technology at our hands today, a celebration and a proposal of advanced usage. Ironically one of the providers of this technology is computer gaming software, whose output is associated solely as a leisure activity of the young and not so young, with little or no academic merit. In a twist of irony, the gaming industry and CNC production provides us with the opportunity of creating a new era of unprecedented detail in our physical world.

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Illustrations

Figure 1. http://allegorithmic.com/
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