EROSIVE FLUIDITY: Exploration in generating digital architectural form

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Abstract. This paper explores emerging digital technologies and their application in architectural design. It investigates the tools and techniques that are currently available and produces some interesting work that is both inspiring and interesting. A series of three scenarios were explored via a digital design studio at the Faculty of Architecture, Design and Planning, The University of Sydney. The final work appeared in the ‘Disparallel Spaces’ exhibition, University of Sydney in May/June 2007. This paper will explain these scenarios and offer a look at some emerging trends in architectural design.

Experiments in Generative Design look at methods of generating complexity through simplistic rules and parametric form, resulting in unique architectural spaces and facades.

Erosion and Cellular Automata explores the system of cellular automata, and uses nature as a vehicle for experimentation. The underlying rules and process behind the natural course of erosion are emulated and encoded via scripting in the software Digital Project. The result is the generation of space that is similar to the sculptural forms seen in the slot canyons of Arizona.

Finally, Erosive Fluidity explores the technique of animation and digitally controlled manufacturing to create a responsive system based in the city. A featureless city is transformed into a vibrant place, embedded with the life and energy reminiscent of an event and the reactions that occurred at some point in time.

There is an opportunity for a new type of architect to emerge; an architect that embraces the digital realm, fluent in the technique of programming, animation and advanced CAAD/CAM software. Advancements in technology provide opportunity for efficiency, complexity and innovation in architecture and it is up to the architects of the future to thrive on this chance. This work demonstrates great potential in the use of emerging digital technologies for future architects.

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1. Digital Experimentation

This section looks into the exploration of new technologies in a digital design studio conducted at the Faculty of Architecture, Design and Planning, The University of Sydney. The first half of the semester involved individual experimentation where I explored parametric design and cellular automata techniques. The final experiment, titled erosive fluidity, was completed as a group and exhibited in the ‘Disparallel Spaces’ exhibition, Sydney in May 2007. The scenarios and their implications will be explained further in this section.

1.1 COMPLEX PARAMETRIC FORM

This section explores the notion of complexity and the idea that complex form can be generated via the use of simplistic rules. It begins by looking at complexity in design, followed by the description of an experiment that uses parametric form and simple equations to generate complex forms, offering inspiration for different architectural spaces.

1.1.1. Complexity and design

Chaos theory delves into the processes and origins of complex behavior. Uncertainties in the initial conditions of a system can lead to unpredictable behavior over time. Scholars from various disciplines have been attempting to decode and use this phenomenon to solve and understand complex problems. Batty (2005) provides an architectural example, attempting to decode the complexity of cities using cellular automata, agent based models and fractals, concluding that highly organized spatial patterns emerge from simple rules and processes.

Although my experimentation does not deal with complexity at the level of these scholars, they do provide inspiration and technique for generating complexity in architectural form. Simple geometry is created and parameterized. The data from these systems are exported into Excel, allowing easy manipulation. The resultant surfaces in image 1 show that a slight manipulation of control points via simple formulas produces forms that are repetitive and complex. The variations in spatial form are achieved by variations in the formula structure used to control the spline data points. The forms are given an increasing amount of complexity by altering both their radius and amount of freedom. The initial result is quite repetitive; however the same system can start to produce complex spatial form. Since the process includes random numbers, an infinite amount of unique designs can be generated.
This scenario is an initial exploration of the idea behind complexity, and the creation of unique, unpredictable forms via a series of simple rules. Whilst the generated forms have not been designed to perform any function as such, they have been carefully manipulated to have a variety of spatial qualities, becoming an inspiration for architectural spaces.

1.2 EROSION AND CELLULAR AUTOMATA

This experiment explores the techniques associated with cellular automata (CA), using nature as a vehicle for exploration. Cellular automata are self-organizing elements that can generate complex behavior via a series of simple rules. They are responsive elements that generate patterns quite often seen in the complexity of nature.

Architects are intrigued by nature and the possibilities it offers for Architectural design. What I believe is of particular interest are the relationship between natural objects and emotion, and the ability of Architecture to drive or even recreating these feelings. In saying this, to understand the beauty of a natural system, one must understand how it works. The rules must be documented and tested, and once it is comprehended, it might be manipulated and controlled for different intentions.

Documented rules can be translated into a language the computer understands. Subsequently, the power of the natural world and computer combine to emulate the rules and systems of nature. Thousands of years of evolution can be simulated in a matter of minutes, and with this control, nature can be manipulated with innovative flair.

Following is a description of a simplified system that emulates the process of erosion. The system is programmed into the computer as a set of manipulative rules, allowing technology to recreate environments that are subject to weathering forces.
1.2.1. Simplified erosion system

This system uses techniques common to Cellular Automata to simulate the natural process of erosion.

A theoretical section is cut through an arbitrary piece of rock. A grid is placed over this section, and each subdivision is considered an indivisible rock entity. Each rock entity in this grid is assigned attributes that will govern its behavior. The key characteristic is the rock hardness, which is assigned to each individual unit via an Excel spreadsheet. Similarly in nature, this is assigned in layers, each row consisting of similar rock hardness. The script then scans all the points, and embeds more attributes based on their environmental status. This takes into account if the rock is in contact with water or air, and how many neighbors it has protecting it.

Once the initial scan is complete, an Annual Erosion process will take place. This will erode the rock according to the condition of each data point. Rock in contact with water will erode faster. The water contact is divided into two types, vertical and horizontal. As the water channels down, the vertical erosion rate is much faster than the horizontal, creating deep erosion ‘slot canyons’.

Elements that are not in contact with water will still be eroded at a slower rate. This is representative of the background wind erosion. The wind erosion rate is affected by the amount of ‘neighbors’ each rock has. The more exposed, the faster the rate of erosion.

Depending on the rock hardness, certain points will erode faster than others. The annual erosion process progressively reduces the hardness value of the rock. When the hardness value reaches 0, the rock is then eroded and is removed. The rocks surrounding this void are now placed in contact with water, and their neighbor parameter is reduced by 1.

After a certain amount of years, the void is plotted into Digital Project. Multiple sections are taken side by side, and lofted together to form a computer generated slot canyon space (Figure 2).

![Figure 2. Grid sections are eroded and lofted together to form slot canyon space](image)

This scenario has briefly explored the use of cellular automata, parameters and scripting to create a system with purpose. Unlike the previous experiment, the system has specific rules that aim to emulate a process of nature, namely erosion. As an initial look into cellular automata, this experiment highlights the fact that complex systems can be generated by simple rules. The key to creating a system is to understand the process before implementation on the computer. Once this research has been conducted, it becomes easier to document the process as a series of rules. There is potential for such systems to be used architecturally, creating buildings that have variety and complexity via their response to their local environment. Whilst this scenario did not progress enough to produce an erosion system that takes into account architectural constraints, it did produce form and a technique that could provide inspiration for future work.

1.3 EROSION FLUIDITY

This section describes the final work submitted for Architectural Design Studio C at the Faculty of Architecture, Design and Planning, The University of Sydney 2007. It was completed by a group of four undergraduate Bachelor of Architecture students under the co-ordination of Dr. Marc Aurel Schnabel. The work was exhibited in the ‘Disparallel Spaces’ exhibition held.
at the Tin Shed Galleries from 24th May – 16th June 2007 (Schnabel & Bowller, 2007). The project consisted of a digital animation and Styrofoam sculpture suspended in the gallery space.

1.3.1 Animation
A short animation created in AutoDesk’s *Maya* tells the story of an object’s pursuit throughout the city (Figure 3). The object takes the form of a liquid entity drifting dynamically down the main street of a featureless city. The energy embodied in this character causes it to pulsate and rush past buildings. The volume of this form expands and contracts depending on its movement and intention.

The embedded power associated with the entity affects the buildings it approaches. A sense of gravity pulls and deforms the buildings as they are embraced with this liquid form. Buildings that have been affected begin to discoulour, slowly altering to a dark green state. As the buildings change state, disease breaks out and a series of bumps start to form, growing in depth over time.

The liquid form is aggressive, and at times collides with the city. This event causes an explosion; particles spray off and freeze in time preserving the memory of the incident. Buildings in the range of the explosion also become exposed and react through discoloration and texturing.

The climax of the animation shows the liquid form in a forceful collision with a high rise building. The main character is affected, and loses velocity. It weaves into the fabric of the city, feeling vulnerable and requiring shelter. It makes a final leap, revealing its physical form in detail, at last seeking refuge in the depths of the city.

What remain are fragments of a featureless city, now embedded with life and energy reminiscent of an event and the reactions that have occurred in some point of time. The importance this animation has for the discipline of architecture lies in the inherent underlying process. Contrary to traditional design methods, this animation provides insight into an inverse process of design, where the buildings respond and change according to events occurring within the city.

![Figure 3.Objects pursuit throughout a featureless city](image)

1.3.2 Manufacturing Complex Form
A suspended Styrofoam physical model compliments the animation.

Reflecting on the research so far, we have seen many models and techniques for generating designs which are unique, variable and complex. One of the most exciting areas of the digital era lies in the advancements of manufacturing techniques. Designs that are documented digitally are now increasingly being fabricated through digitally controlled machinery. These machines offer potential to construct complex 3D form which was previously very difficult. Understanding the language of the machine also offers great potential to further improve designs. Knowing the limitations and technique of the various machines and materials widens the possibilities for manufacturing your design to the quality and finish desired.

This model was created using a 3D CNC Router. It was documented and designed in Maya and separated into individual components based on the size limitations of the machine. Individual components were arranged onto sheets to maximize production and minimize material waste. These were later separated and cleaned up using a hot wire. Experimentation in tool speed, cutting depth and tool bits allowed us to customize the look and feel of our final...
product. Careful planning in the modelling stage allowed us to sculpt individual 3D forms which connected together into a master artwork curving in three dimensions (Figure 4).

Figure 4. Suspended complex form created using a CNC Router

2. Conclusion

We are constantly observing more tools and techniques from various disciplines being integrated into architectural design. In the search for a more intelligent architecture, architects have drifted to methods commonly found in computer science, physics, geology, animation, aviation and automotive fields. This work demonstrates great potential in the use of emerging digital technologies for future architects.

References


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