THEME: MATERIALITY & AESTHETICS

Interfacing Design and Making of Ceramics:

Expansion of ceramics practice through technology

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Abstract

The dawn of digital fabrication technologies questions the relationship between crafting materiality and its digital representation. This paper presents a way experiential knowledge of crafts, which is rooted in ceramics, can be transformed and utilized in the use of digital technologies. In this research, materiality through technology is considered in an extended way. Firstly, being the result of the interaction of a designer with the responding matter (in this case clay) and secondly, the process (3D printing, firing and glazing).
The project used design as a method of inquiry, reflecting on action and through action. Through experimentation the research question, concept, digital technology and ceramic material have been tested, evaluated and iteratively refined.
Through the experiment a computational interactive system for designing wall-like compositions made up by modules in ceramics, which modulate light, has been developed. Material processes form the basis of the design technology, which holds process and material knowledge and informs ornamentation steered by the movement of the hands. Crafting and its execution become a unity again. Fulfilling performative and aesthetic purposes, printed ceramics express the playful and light movements of the hands, and simultaneously, the presence of materiality.

Keywords: *Ceramics, 3D digital interactive system, 3D printing.*

Introduction

Following Senneth (2008), technology often seems to take us away from the material. The need to create representations prior to the engagement with material, as when we engage with 3D printing of ceramic material, prohibits appraised methods of making, which is considered key to craft and artistic practice. These practices are based on the idea that direct physical and tactile interaction with a responding material guides the ceramicist (Leach, 1940, Dormer, 1994), and crafting and execution works as a unity that is intuitive and humanistic (Leach, 1940).

Rather than thinking in diametric positions, this research proposes to see technology as an enabling force and follow McCullough's (1998) idea about a close connection between digital work and craft practice. Focusing on practices with ceramics, we pose the question: how and where can traditional craft based knowledge, routed in skills and experience of making three dimensional objects, be implemented in novel ceramic processes, which utilize digital technologies?

Following Leach and Dormer, we argue that traditional craft can be understood through two parallel levels: its immediate interface to matter, which is able to provide instant feedback, and through the consistency of design logic and material process.

Novel digital approaches create new interfaces and processes between human, space and material. Advances in 3D motion capture technology and sensors allow us to capture spatial hand gestures and body movement in real-time. At the same time, digital technology such as 3D printing with ceramics, allows us to create a bridge between the digital design environment and fabrication.

This research investigates how these technological developments open spaces for new expressions and allow rethinking of traditions in ceramics, while enabling the designer's body to be involved in the making once again.

On the Properties of Materiality in 3D Ceramic Printing – As the dominant amount of 3D printing approaches focuses on the materialization of arbitrary shapes, material is often sidestepped. In a two-step process, the digital representation of a designed shape is first sliced. A second step introduces support material in places of the shape that defy gravity. While current research focuses on minimizing this support, using for instance inbuilt simulation processes (Schmidt, 2014), one can consider this as post processing of an approach that is at its core agnostic to questions of matter. It removes the materiality from the printed part.

In this frame of the project, we understand materiality in an extended way. Firstly, being the result of the interaction of the designer with the responding matter (in this case clay) and secondly, the process (3D printing, firing and glazing). Our approach aims to include the knowledge of materiality into a holistic approach.

This takes place on the level of material processing through the creation of a bespoke design and fabrication process that is built upon the very genesis of shape in 3d printing with clay: the extrusion of a line of material. This thinking, in a continuous path, is finally the point of departure for our design and making.

Method

Design in our research project, is used as a method of inquiry, or a reflective practice in which the designer engages in a dual mode of reflecting on action and through action (Schön, 1993). Moving between the exterior and the interior of making, design creates a conversation between the dissective action of analysis and critical assessment, and the creative action of proposition and result.

A series of parallel and interdependent introductory experiments with digital technology and ceramic material formed the starting point in this research. The experiments acted as inquiries by which the concepts, technologies and material were tested and evaluated within a wide frame of possibilities that reflected the overall research questions in a very general way: what is possible and how? The introductory experiments gave rise to new questions and experiments. At the same time these helped to focus the research as they established a growing framework that helped to evaluate and verify the results as the experiments grew larger and larger in scale over time.

The final experiments should, nevertheless, not be seen as final results, but as representative examples of experimentations that reflect the dynamic and unique possibilities in the cross border between digital and ceramic crafting.

Experiment

The experiments were situated in a context that allowed the combination of specialized knowledge of ceramic material, and architecture with digital technology in an interdisciplinary platform. Our design ambition was to enter the architectural realm with ceramics. Ceramics has a tradition of being used as wall elements. The observation of the filigranity of the extruded ceramic thread inspired us to look at references from Gothic and Arabic windows, whose filigree patterns fulfill functional purposes (the subdivision of a larger wall opening into batches of available glass sizes), performative aspects (to provide shadow), and aesthetic purposes (create local shadow figures).

The experiments were simultaneously embedded in a lineage of research into digital fabrication in architecture. This created precedence for design strategies that make fabrication approaches an integral part of design thinking. This integration is often deep, and results in computational design systems that hold all knowledge of the design and fabrication process and output code that can be directly fed into the production machinery. This code describes many machining processes for the movement of the tool. Researchers linked the generation of 2d milling paths to the design of the ornamentation of surfaces (Strehlke, 2005), or the three dimensional movement of robots to the extrusion of acoustically active expanding foam (Gramazio, 2008).

The process of our early experimentation resulted in a sketch of the concept for a computational system for designing wall-like compositions based on modules in ceramics that modulate light. This computational system negotiates between the design intent, expressed in the interactive movement of the designer's hands, the 3D clay printing process and the following steps, such as firing and glazing, which further influence the shape and appearance of the product.

Preliminary Experiments: Material and technology

The creation of an environment that is able to hold the whole process, from capturing the designer's hand movement to 3D printing, is a complex endeavor, which we did not want to further confuse through a heterogeneous development environment. The 3D modelling software, Rhino (Robert McNeel & Associates) and its graphical programming interface, Grasshopper (developed by David Rutten) provided a single software that could satisfy all needs. It is possible to interface a Kinect developed for the video game console Xbox (*http://www.xbox.com/en-US/Kinect*) for

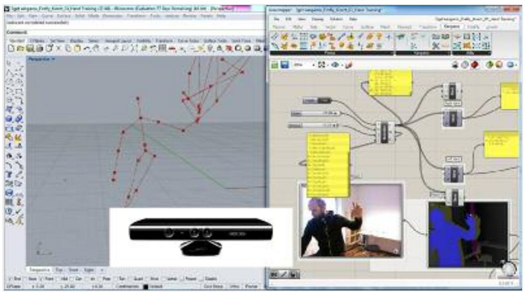

Image 1

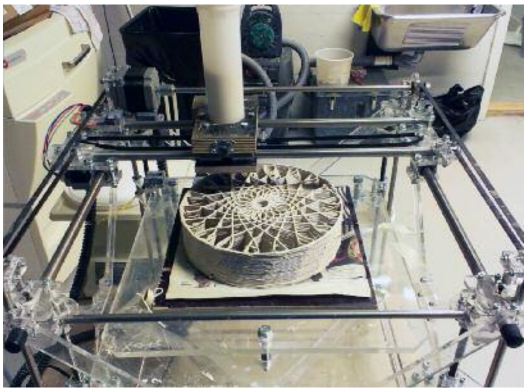

Image 2

Image 1. The Kinect captures the designer's hands movement, which is inputted to the computational system that was developed in the plugin, Grasshopper, for the 3D modelling software, Rhino.

Image 2. The RapMan utilized for 3D printing with clay.

capturing the movement of hands on the one side (see image 1), and interface the RapMan 3D printer (*http://www.rap-man.com.au/*), on the other.

The project utilizes the RapMan for 3D printing in clay, a technique developed by the Belgian design duo UnFold (*http://unfold.be/*), and introduced into our context by the ceramic artist Jonathan Keep (*http://www.keep-art.co.uk/*) (see image 2).

The Physical and Parametric Module

The modules of the wall like composition are based on the material process of the RapMan printer: they follow the logic of a continuous coil, which allows the printer to build all its layers in a module without pause (see image 3). The pattern generated in the computational tool follows the principle of a continuous curve (see image 4).

A continuous process of iterations of physical prototypes with the RapMan printer and the careful registration of the results allowed us to tightly link the behavior of the ceramic material to the development of the parametric module.

The prototyping provided us with an understanding for the need for internal support of the walls. We observed that modules with straight, unsupported *walls* deform easily. This led to the invention of inner stabilizing patterns for the modules. These structural needs provided a rich ground to include further functions as ornament and light filter (see image 5).

Prototypes also led to an understanding of maxima and minima, which resulted from the interplay of technology and material. The maximum sizes and height of the modules and the shift of layers were, for instance, simultaneously defined by the RapMan dimensions as the shrinkage of the material.

The undulating curve carries all the information needed for the printing. It constitutes both the outer boundary of the module and the inner supporting patterns. The inner pattern can be modulated between a pattern of straight lines and curves, for both aesthetical and light performance.

The amount of empirical knowledge gained through prototyping (the sheer amount of possible combinations of parameters), necessitated a classification into two types of parameters:

1. Interdepended parameters, which are directly related to another parameter and cannot be user controlled.
2. User controlled parameters, which can be controlled, but is at the same time depended on or are constrained by other parameters through simple formulas derived from empirical studies of the printing and material behavior.

The verification in further iterations resulted in a parameter space that allowed to define the single, as well as the composition of many:

1. Module position: User controlled. Not depending on any internal or external parameters. Positions the module in 3D space.
2. Radius of the module: User controlled. Constrained by the printable area of the RapMan printer. Sets the size radius of the module.
3. Height of the module: User controlled. Constrained by the RapMan printer and material. Specifies the amount of layers for the continuous curve.
4. Amount of supporting inner patterns: Interdepended. Depended on the radius of the

Image 3.
The code informs a RapMan 3D printer to print directly in porcelain layer by layer.

Image 4.
The concept of the module and the parametric setup are based on this principle of a continuous curve.

Image 5.
Prototypes of the inner stabilizing patterns of the modules, which at the same time functions as ornament and light filter.

Image 6.
Through the interaction the size and pattern emerge and change in real time and in smooth steps, according to the movement of the hands.


Image 3


Image 5

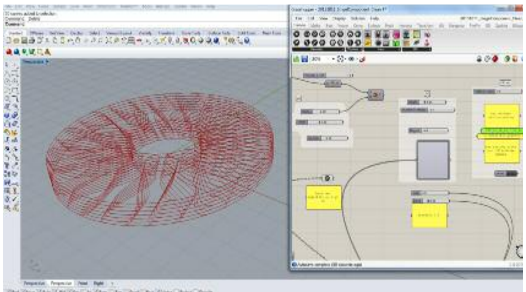
Image 4


Image 6

module. Changes the amount of meeting points between inner pattern and outer rim of module.
5. Radius of the inner hole of the module: User controlled. Depended on the radius of the module. Changes the radius of where the inner pattern ends towards the middle of the component.
6. Curvature of the inner pattern: User controlled. Constrained by the behavior of the material. Changes the curvature of the inner pattern.
7. Shift/twist of layers: User controlled. Constrained by the material behavior, depended on the radius of the module. Rotates each layer by a certain degree.
8. Shrinkage: Depended on the material, firing and glazing. Scales the printing curve up so module, after shrinkage, fits drawn size.

This parameter space can be directly accessed and controlled by the user through number sliders or through the interface of the interactive system, while the inbuilt computational rules make sure that the constraints from the printing process or the material behavior are maintained.

The resulting continues curve is subsequently translated through a custom python script into G-code, which is readable by the printer. After printing in porcelain the modules are glazed and fired to 1280 degrees.

The Interactive System

While the parametric system holds the knowledge about the process and the design of a single module, an interactive system is set up to interface with the overall composition of the modules. The system consists of a Microsoft Kinect, which is interfaced to Grasshopper (Firefly) (*http://www.fireflyexperiments.com*). The Kinect captures a point cloud from which the position and movements of the hands can be extracted and utilized as parameters for the parametric modules.

The movement of the designer's hands is recorded and transformed into a trace of cylindrical modules by the computational system. Through the interaction, the size and pattern of the module emerge and change in real time in smooth steps according to the movement of the hands (see image 6). Over time, each module changes pattern and reduces its size and it disappears or can be manipulated by new interventions. Finally, a trace of modules can be captured (see image 7).

The point of departure for the overall composition of the circular modules is that these want to be packed as densely as possible. This physical behavior can be resembled in computation through a circle-packing algorithm (initially a C# script by Daniel Piker, later to become MeshMachine). Our script uses a dynamic approach to circle packing, where the variation of the sizes of circles depends on the relative spatial position of the hand of the user over time. The hand of the user can be traced, and modules can be laid out according to his movements. Our experiments resulted in a framework that guides the interaction: the process

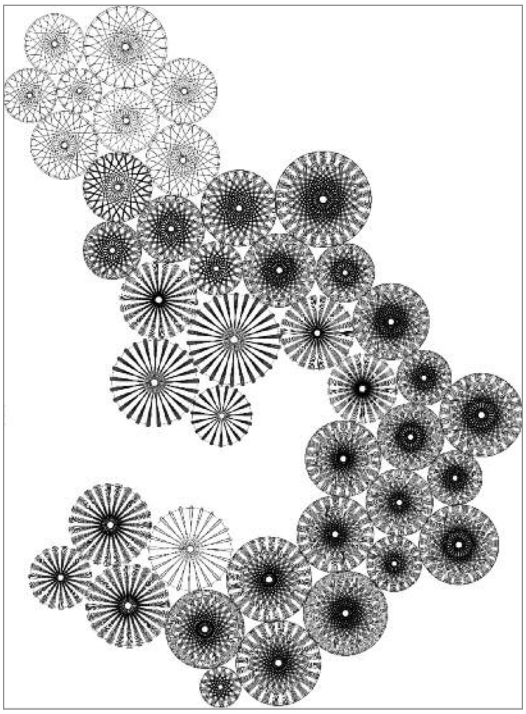

Image 7

Image 7. A wall like composition has been captured and each module is ready to be printed directly in porcelain by the RapMan 3D printer.

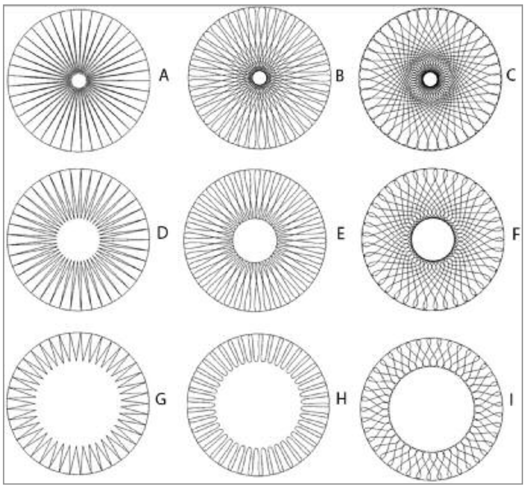

Image 8

Image 8. Basic scheme and variations through shift of parameters that was triggered by design interaction.

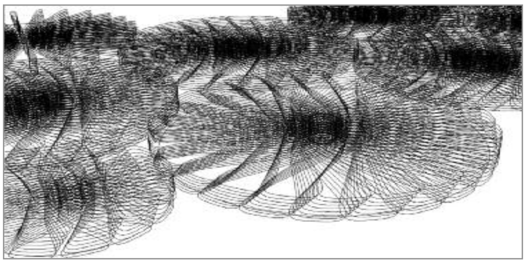

Image 9

Image 9. The layering can be twisted according to the position of the hand.

Image 10

Image 10. The ceramic modules were mounted in a laser cut transparent acrylic board.

starts when the hand enters a specified physical volume in front of the user. The sizes of the modules depend on the speed of the movement in xy coordinates according to the drawing plane. The faster the hand is moving, the larger the module will become.

We interfaced furthermore internal parameters of the parametric module to the movements of the hands: the movement in the z-coordinate to the drawing plane of the separate left/right hand. Image 8 shows the basic schematics.

1. If the user moves their left hand in the z direction the inner pattern will change from A to B to C (see image 8). Thus, the inner pattern will gradient from straight to curved.
2. If the user moves their right hand in the z direction, the inner pattern will change from A to D to G (see image 8). Thus, the radius of the inner hole will change.
3. Or the change can be defined by a combination of 1 and 2, as a change from A to E to I.

Continuous experimentation provided insights, which of the parameters for the modules, could be linked to the designer's movement that would provide them with meaningful control and feedback from the interactive system:

1. Module position: Modules are laid out according to a distance threshold from the xy-position to the drawing plane of a hand within a specified volume.
2. The radius of the module: The speed of the movement in xy-coordinate to the drawing plane of the hand explicitly sets the radius of the modules, but this is also implicitly affected by the radius of the neighboring modules by the circle packing algorithm to enable this packing, which in turn gives a gradient of radii.
3. The height of the module: Fixed in this experiment.
4. The amount of supporting inner patterns: Not interfaced by the interactive system. Totally dependent on the radius of the module.
5. The radius of the inner hole of the module: The position in z-direction to the drawing plane of the right hand determines the radius of the inner hole. This works on a threshold area which affects neighboring modules to create a gradient.
6. The curvature of the inner pattern: The position in z-direction to the drawing plane of the left hand determines the radius of the inner hole. This works on a threshold area which affects neighboring modules to create a gradient.
7. The shift/twist of layers: The speed of movement in z-direction to the drawing plane of the hand determines the amount of twist. This works on a threshold area which affects neighboring modules to create a gradient (see image 9).
8. The shrinkage: Not interfaced by the interactive system. Totally dependent on the material, firing and glazing.

Rules were implemented that checked, for instance, whether a module already existed at a gestured position. If so, the already existing modules and any interrelations between them were affected by the movement. If modules are left *untouched* they will, over time, gradually untwist and shrink until they finally disappear. This behavior constantly engages the user, and presents an effective means to create a dynamic interplay between user and system.

When a desired layout is formed the user steps out of the drawing volume and stops the system. The captured pattern is then exported as G-Code and sent to the RapMan printer.

Exhibition

For dissemination in an exhibition the compositions of ceramic modules were mounted in laser cut transparent acrylic boards (see image 10) based on three different captured stills.

The transparent acrylic boards emphasized the lightness and flow in which the modules and the captured composition were made. The light movements of the hands were reflected in the smooth changes in size and pattern of the modules.

At the same time, and as a contrast, the materiality made the movement of the hands present. The strong materiality was developed in interplay with strong light coming through the ornament. They were light filters playing in and through the glossy glaze. In that way, the filigranity, made by the printed ceramic, fulfilled the performative and aesthetic purposes.

The exhibit showed and emphasized the quality of the computational system to negotiate between the design intent, expressed through the movement of the designer's hands, the 3d printing process and the materiality.

Reflection and Conclusion

The focus of the research was the investigation into the relationship between crafting materiality and its digital representation, and how experiential knowledge of crafts, rooted in ceramics, can be transformed and utilized in the use of digital technologies.

We have explored how novel digital approaches can create new interfaces between the human, space and the material. For this purpose, we have utilized a Kinect for capturing movements of the designer's hands, the graphical programming interface, Grasshopper, for developing an interactive system, and a RapMan 3D printer for printing in clay.

Through experimentation we developed a computational system for designing wall-like compositions made up by modules in ceramics that modulated light.

In this project we have explored materiality within digital technology in an extended way. Firstly, being the result of the interaction of a designer with the respoding matter (in this case clay) and secondly, the process (3D printing, firing and glazing). The research provides insights into how these concepts can be transformed into current digital practice when constituting material processes are becoming integral part of the design genesis.

Prototyping gave an understanding for the needs of an inner stabilizing pattern of the modules, which at the same time functioned as ornament and light filter. A parametric module has been linked to an interactive computational system that negotiates between the movement of the designer's hands and the 3d clay printing process. In this way, the hand of the designer can be traced and modules laid out according to the movements.

This link provided a means to transfer the position that bodily movement has in traditional craft processes into the realm of digital tools. It became meaningful as a mediator of complexity. The different ways the parameters can be linked reflects unforeseen complexity that can emerge by interaction. The complexity is to be experienced by the physical interaction through the movement of the hands. Thus, the experiment shows how the involvement of the body is being exploited in the use of digital technology based on the idea that crafting and execution is a unity that is intuitive and humanistic.

Bodily engagement provided a powerful means to gain overall control. This, as a single gesture, could control multiple parameters across a full set of many modules. In our exploration of the computational system we found it a challenge to identify how many parameters can be directly controlled by the hands at one time. We found that the selection of too many can easily create the feeling of random selection and a loss of control. It was, furthermore, a challenge to validate how many parameters make sense in an artistic expression. We found that too many different expressions weaken the power of the artistic result.

The developed interactive system reached it limits when the designers' focus shifted from the overall to the particular. The notion of gradual refinement, constitutional to many artistic practices, is not supported by the developed interactive tool. The setup of the parametric system allowed, when needed, a shift to more appropriate tools of refinement.

The main finding was the potential in the use of the parametric setup that directly informs ornamentation by the movement of the hands. Through the interaction the size and pattern of the module emerge and change in real time in smooth steps according to the movement of the hands. At the same time and as a dynamic contrast the materiality in the 3d printed and glazed modules made the movement of the hands very present.

Acknowledgments

The research took place within the frame of the project 'What Does It Mean To Make An Experiment?' A two year research project that investigates the position, role and significance of the experiment within design-led research funded by an internal grant of the Royal Academy of Fine Arts, Schools of Architecture, Design and Conservation.

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