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Smartphone-based vase design: A developing creative practice

This article describes a developing creative practice whereby digital creative processes adapted from mobile music making are used in the data driven design and subsequent digital instantiation of ceramic vessels. First, related work in mobile music creation and recent developments in the digital design and fabrication of ceramics frames the research and puts it in a broad context. A pilot study is then detailed, concluding that although largely successful, a number of areas of the process needed to be improved and refined. The results of a further iteration of the process, consisting of the digital creation and instantiation of location-specific vessels is presented, before the current state of the research, where ceramic vessels are 3D printed, is outlined. We show that mobile phones can become integral to a practical design process that allows the digital forms it creates to be instantiated using 3D printing, and that these become high-quality, end-use artefacts. The final section discusses what has been learned and contemplates how the described practice will be developed yet further.

Introduction

The rapid developments in generative and parametric design methods and 3D printing allow the creation and instantiation of an almost infinite range of forms. It is no longer the case that designers are limited to only designing forms they can imagine and draw and model with more traditional design tools. Nowadays, smartphones have many features that make them suitable for use as a generative design tool. They have high-resolution screens, in-built sensors and, although they do not have the processing power of desktop or laptop computers, they have the capability to process real-time data that can then be used to generate three-dimensional digital models. However, despite these highly portable and familiar devices becoming virtually ubiquitous, and making these features accessible to almost all, they are rarely utilised for innovative design processes.

The developing practice described in this article set out to build on work carried out in the field of generative, mobile-based music, where the smartphone becomes a tool for creative tasks. It explores the feasibility of allowing the generative design process to take place anywhere, and result in the creation of 3D models based on data captured with and processed by, the mobile device. The resulting digital files are then 3D printed, instantiating the forms as physical objects.

Literature review

For over a decade, research into the use of mobile phones as musical instruments has identified and embraced many of the advantages of smartphones previously summarised. For example, Essl et al (2008) describe developments and challenges in making mobile phones become a stand-alone, generic tool that facilitates generative, creative expression. Essl's (2009) SpeedDial uses accelerometer sensor data and keystrokes from a mobile phone to generate and manipulate musical output in real time. Oh et al (2010) describe Herrera's interV mobile music performance, where the touchscreens of iPhones are used to control music performance, and the accelerometer is the principle expressive control i.e. controlling the volume of musical notes. Of particular note are the reasons for using mobile phones, as highlighted by Wang et al (2008). When discussing the MoPhO (Mobile Phone Orchestra), a musical group who use mobile phones as their primary instrument, they argue that this is, in part, because mobile phones are ubiquitous, portable, and powerful enough to allow the creation of music anywhere (Wang, Essl and Penttinen, 2008). Tanaka argues that by democratising access to sensor technology, mobile phones allow for new forms of expression (Tanaka, 2000) and new cultural contexts for

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interaction (Tanaka, 2010); properties which apply equally to design as they do to music.

Exploration of printed ceramics has become increasingly common (Eden, 2008–present; Hardie, J. and J., 2014–present; Keep, J., 2013–present), among others. Recent work has touched on digital design and manufacturing, notably Stratigraphic Manufactory (Unfold, 2012) where the same digital files were sent to different ceramic 3D printing production centres so that each printed cup was unique due to different production conditions or errors. More recently, in Adaptive Manufacturing (van Herpt and Wassnick, 2014–2015), information measured by external sensors control a 3D printer, and in Solid Vibration (van Herpt and van Broekhoven, 2015) sound waves cause the 3D printer bed to vibrate during the manufacturing process, creating Moiré patterns in the printed vessels.

Although these ceramic designers are working in a similar area, this research approaches the design process in a different way. It envisages an approach more akin to that used in mobile music creation, where the in-built capability of highly portable mobile devices to record, process and display data is at the core of the creative process.

Developing a creative practice Why ceramics?

The intention of the research is to develop and test an experimental design process in a real-world scenario. While the research approaches the design process from the direction of creative technology rather than of product design, a series of objects need to be designed and instantiated to provide a practical application. Vases meet a number of requirements needed to fulfil the research. Firstly, while the body of research into digitally designed and manufactured ceramics is growing, there is still much scope for research into new creative practices. In addition, while vases are functional, they are also intended to be decorative, meaning there is an opportunity to create unusual forms; an abstract form will not necessarily make a vase less functional. Also, as the research is being carried out in Taiwan, there is cultural significance in using miniature vases as the subject.

Research aims and methods

The research set out to investigate whether mobile phones, and their inherent ability

to record and process data from sensors, could become integral to a practical design process. It also investigated whether this design process allowed the digital forms it creates to be instantiated using 3D printing, and ultimately whether these could be high-quality, end-use artefacts.

Three iterations of the creative process are described in this article and these are briefly summarised below. Broadly, a pilot study (Found and Lin, 2015) was intended as a proof of concept, exploring the technical feasibility of the process. It is given a more thorough summary as the results formed the basis of a further exploration of the process consisting of the digital creation and instantiation of location-specific vessels (Found and Lin, 2016). Finally, the current status of the research, where ceramic artefacts are digitally manufactured, is outlined.

Exploration 1: Accelerometer pilot study

Aims

The study, originally presented at the IASDR 2015 INTERPLAY conference, held in Brisbane, Australia during November 2015, had two broad aims. Firstly, it tested the overall functionality and usability of a prototype smartphone app, including uncovering areas where it could be improved. Secondly, it assessed whether vases that had been designed using the app could be successfully manufactured.

Method

The pilot study itself consisted of two parts. Part one required participants to use a prototype application to design vases during a workshop session. They then reflected on their experiences. Part two consisted of the designed vases being 3D printed to determine whether the design process was successful in producing manufacturable forms.

Application overview

Processing for Android software was used to create the app. It was compiled for use on a smartphone running the Android operating system. The app allowed users, via movement of a smartphone, to change the shape of a generic vessel model. This worked through the capturing and processing of real-time accelerometer data. Movement on the x axis decreased (tilt forwards) or increased (tilt backwards) the number of vertical sections. Movement of the y axis controlled the number of twists the vase has in an anti-clockwise (tilt left) or clockwise (tilt right)

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Figure 1: Smartphone movement used to create vase design



Figure 2: Successful 3D prints (Designer Group)



Figure 3: Successful 3D prints (Non-Designer Group)



Figure 4: Unsuccessful 3D prints

direction. When used together with tilting on the x and/or y axes, movement on the z axis increased or decreased the vertical radius of the sections. Simultaneous processing of movement on all three axes is possible. Additional Points – and Points + buttons allow the user to increase and decrease the number of points around the circumference of the vase. For example, one point creates a circle (default), and seven points is similar to a star with rounded end points.

The choice of accelerometer data enables the user’s hand movement to be measured. Often, when designing or creating form, the hand is used to draw or sculpt. The mobile phone and associated app are an innovative way of recording, processing and using this movement in real-time. The sensor data are mapped to upper and lower limits to try and prevent extreme forms being created, and thus ensure they are printable. Users can stop the app to view the vase form they create by pressing a Start/Stop button. They can then either export the model as an STL file ready for printing by pressing a Save Vase button or, restart the app to create further forms by pressing the Start/Stop button again.

Testing the application.

To assess the functionality and usability of the app, it was tested by two groups of seven users. One group consisted of designers, the other of non-designers. For the designer group, subjects were drawn from the cohort of Masters and PhD degree design students at National Chiao Tung University’s Institute of Applied Arts. The non-designer group consisted of participants with no background or training in design. All the participants are familiar with using smartphones and apps.

During the workshop, participants were told the reason for the study, the purpose of the app and how to use it. All participants used the same smartphone. They familiarised themselves with the app, then were asked to create vases in real-time (Figure 1). The participants each created three forms, which were exported to the smartphone’s SD card as STL files. These were then shown to each participant in an external STL viewer. Each participant selected his or her favourite, to be printed.

Participants were then asked about their experience of using the app. A questionnaire was given to them immediately after they had used the app, to record their thoughts

and feelings. Participants were also given the opportunity to offer more open comments and expand on any feedback given, to improve the usability and functionality of any subsequent iterations of the app.

Results

The app-based design process was shown to work, as the design and non-design participants all successfully created a 3D digital form using the app, and many of the vases, though not all, were successfully printed. Although most of the vases printed successfully (Figures 2 and 3), others had features that were too fine or complex to print, resulting in failed prints, incomplete vases, or prints that required additional support material that then proved impossible to remove without breaking the vase (Figure 4).

Both groups of users found the app simple to use and the overall process appealing but for slightly different reasons. The designers were intrigued by the creative process itself, and thought it would be useful as a 3D sketching tool for quickly generating and testing unusual forms. The non-designers however, were more interested in the outcome, and expected a broader range of high-quality artefacts to be produced. As shown by the failed prints, the forms actually needed to be constrained further to ensure they were printable, but the desire for end-use products reflected the ultimate aim of the research. That the app was broadly successful was encouraging, and formed the basis of the next creative exploration.

Exploration 2: location vases

Background

The second exploration developed the pilot study for inclusion in the “In This Place” Cumulus conference, held at Nottingham Trent University in April–May 2016.

Aim

The aim was to assess whether vases designed and manufactured using a refined iteration of the described process offered an innovative interpretation of place, whereby the concept of “here” and “there” have unique, demonstrable characteristics. To explore this idea, a generic vase form was exported in digital form, but re-imagined using data from location-specific markers, before being instantiated in a single location. The intention was to create a series of vases which reflect the unique location in which they were digitally generated.

Method

The study required participants to use an app to design location-specific vases and send the created STL file back to the authors to assess whether they were unique. These vases were then 3D printed to test their validity.

Application overview.

The generic vase form is generated as soon as the app runs, and instantly transformed using GPS data derived from the user's current location. The vase has a vertical dividing line meaning that while one half of the vase form is redesigned through the transformation of vertices, the other half retains the original form. The app uses decimal degree (DD) notation where latitude is measured from -180° to 180° , while longitude is measured from -90° to 90° . 1° latitude or longitude represents one unit of deformation.

The transformation is based on Perlin noise, and has the appearance of being random (Perlin, 1999). By default, the noise function would use a different algorithm each time the app is run. However, the app is constrained to always use the same algorithm. Latitude drives the horizontal noise, while the longitude drives the vertical noise, with higher values giving greater amounts of transformation. In this way, the differences between vase transformations are determined only by the latitude and longitude of the user's location. The transformed half thus provides a visual representation of "here".

After installation, the app's simple interface consists of three elements. A static, but accurate, 3D representation of the generated vase is displayed in the centre of the screen. Below, the location of the user – and their mobile device – is presented as longitude and latitude, to six decimal points. At the top of the screen is an "EXPORT" button rendered in bright pink to make this function, the only one the users need, obvious (Figure 5).

Testing the application.

Participants used the app to create location-specific vases. The participants were a diverse group, with their common characteristics being a willingness to take part in the study and ownership of an Android device. They were, however, divided into two distinct groups, with one group of three located in the United Kingdom (UK Group), and another group of seven (World Group) scattered across the globe in various locations namely

Taiwan, Japan, Sweden, Slovakia, Ireland and Peru.

An app was distributed to participants via e-mail, for participants to install on their own mobile device. Instructions on how to install and use the app were provided. As the vase forms are generated automatically, and are influenced solely by the location of the user, the installed app only needs to be opened once. Participants noted down, or took a screenshot of, the GPS data displayed on the screen, and then pressed the EXPORT button to save the generated vase as an STL file. These STL files were then e-mailed back to the authors, with the GPS data used as location references to identify the created vases.

Results

All 10 participants managed to install the app, create a vase and e-mail the required STL files to the authors. Most encouragingly, all the files proved to be suitable for 3D printing. This demonstrated that in terms of basic functionality, the app and the process it affords work as intended.

Although the vessels designed by participants in the UK Group (Figure 6 and Figure 7) and World Group (figure 8 and figure 9) are very similar to one another, distinct differences can be seen in the digital models. This demonstrated that the described process allows a series of similar but different vases to be designed using a smartphone app that records and processes location data.

To investigate whether the files were suitable for physical instantiation, an Ultimaker 2 3D printer was used to produce thin-walled prints of the vases, 170mm high by 100mm in diameter. Each of the 10 vases in the series printed successfully (Figure 10). The physical artefacts also highlighted the differences between each vase much more clearly than the digital renderings.

These results allowed the research to move to the final stage of the process, namely 3D printing the designs in a ceramic material.

Exploration 3: ceramic vases

Background

The use of plastic material for high resolution 3D actualisation was adequate for the early stages of a creative process that could broadly be described as a proof of concept, but not satisfactory for the broader aims of the research.

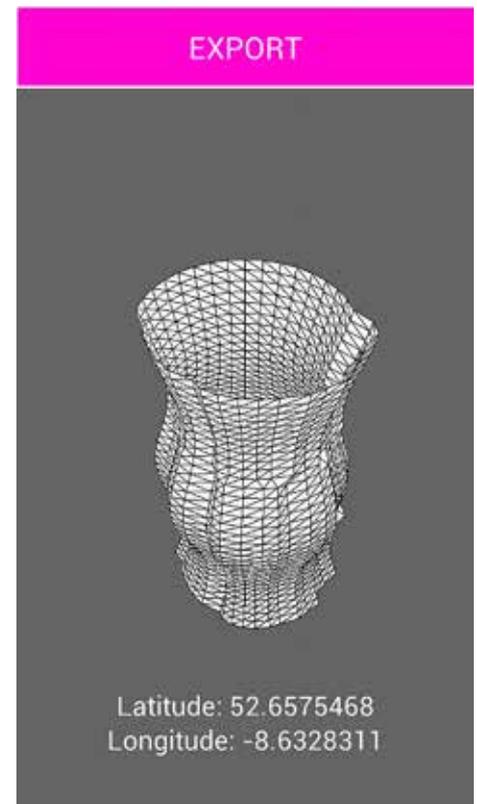


Figure 5: App user interface

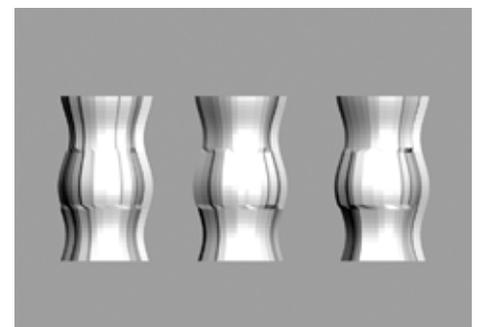


Figure 6: UK Group vases (digital rendering – front view)



Figure 7: UK Group vases (digital rendering – bottom view)



Figure 8: World Group vases (digital rendering – front view)

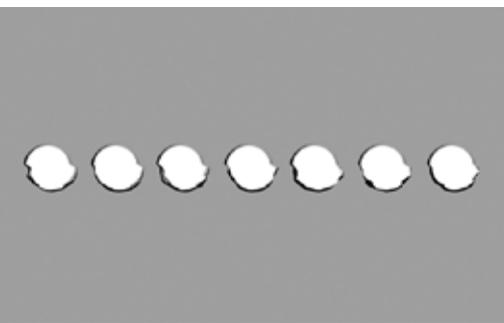


Figure 9: World Group vases (digital rendering – bottom view)



Figure 10: Location vases series (3D prints, white ABS)

Aim

The aim of the final exploration was to use the digital files created previously to directly manufacture ceramic vases via 3D printing processes. While they had proved to be successful when printed using plastic, demonstrating how the app is supposed to function, printing the vases in a higher quality material would not only satisfy the aim of producing end-use products but also enhance their aesthetic value.

Method

The location-related digital models had all proved to be manufacturable as physical artefacts. Any failure during manufacture could be attributed to limitations in the manufacturing process or the unsuitability of the vase forms for the process, rather than problems associated with any newly created files. As these digital files already existed, all that was necessary was to attempt direct manufacture.

The STL files were sent via e-mail to Yao van den Heerik and Marlieke Wijnakker of VormVrij® | 3D, Den Bosch, Netherlands. Designers and manufacturers of LUTUM ceramic 3D printers, they offered to produce a limited number of vases (three) for this research. The researchers let them decide which of the vases they would print, and those representing Taipei (Taiwan), New Romney (UK) and Satipo (Peru) were selected.

The manufacturing process is similar to common 3D printers in that a constant flow of material is used to build up the vase layer by layer. However, rather than heated plastic, the material is clay, forced through the printer head nozzle by pressurised air. For the three vases, a 3mm nozzle was used to expel clay in 1mm layers. Each vase measures 170mm high by 100mm in diameter. The completed vases were then kiln fired at 1230°C.

An opportunity arose to visit ceramic artist Jonathan Keep at his studio. The intention was to learn about Keep’s working methods, but he also offered to print a vase in French porcelain via a specially adapted DeltaWASP 3D printer. As the app was readily available, a new vase form was created at the location of his studio and used to directly manufacture a vase. The layer height was 0.6mm. It was of similar size to the stoneware pieces. The print was later bisque-fired without glazing. While unique among the location-related

vases in that it was created both digitally and physically at the same location, like all the others it demonstrated that the generated file can be used to directly manufacture an end-use physical object.

Results

The three stoneware vases printed successfully, and retained a level of detail that demonstrated the subtle differences between them (Figure 11), but they are of a much greater aesthetic and functional quality than the plastic versions. The porcelain vase also printed successfully (Figure 12).

These vases were sufficient to conclude that the described creative process does allow high quality, end-use products to be designed and manufactured. The vases are intentionally left unglazed to avoid hiding their textural qualities. The layers created by the 3D printing process, being an integral part of the production process, are not supposed to be hidden, but are instead part of the design.

Discussion and conclusion

This article presented an overview of a developing personal practice. The research set out to investigate whether mobile phones, and their inherent ability to record and process data from sensors, could become integral to a practical design process. It also investigated whether this design process would allow the digital forms it creates to be instantiated using 3D printing, and ultimately whether these could be high-quality, end-use artefacts. The described research has succeeded in meeting these aims through three series of designed and instantiated objects. It does not however explore the full potential of the process and there are limitations that must be acknowledged.

The types and forms of the ceramic object that could be created were very limited. While this was necessary for the purposes of the research aims, more aesthetically meaningful and exciting objects could be produced if these restrictions were eased. Although the focus was very much on the design process, this is certainly something that should be considered as the practice moves forward.

Future work should take account of more than just one source of data. While a single source, whether hand movement or location,



Figure 11: 3D printed stoneware vases



Figure 12: 3D printed porcelain vase

was sufficient in the described studies, mobile devices are capable of measuring data from numerous sources simultaneously, and this should be explored more deeply. For example, location used in conjunction with other data sources would provide a more rounded visualisation of the differences between locations.

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