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Customizing personal objects: a pilot study using a smartphone to "design" a mini vase

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Abstract

This research tests a prototype design application (app) that uses real time sensor data, captured and processed via a smartphone, to generate a series of unique vase forms. Smartphone technology, with the support of embedded sensors, the app, and 3D printing processes, are applied in the design and instantiation of the vases. The users' feedback on the complete process is also examined.

The research found that the described design process could be successfully applied to the design, and ultimately manufacture, of unique vase forms. Users stated that the app was easy to use, and allowed them to create intriguing forms they could not otherwise design. While both designers and non-designers found the app usable, they had different expectations from it. This uncovered areas where future iterations of the app could be improved.

Mobile Devices; Sensors; 3D printing; Generic design tools; Data-driven design

Generative and parametric design, and digital additive manufacturing (3D printing) allow the creation and instantiation of an almost infinite range of forms. Designers are not constrained by only being able to design what they can imagine. Architecture has used such methods for several years, and there is growing interest in generative methods in industrial design. The customization or individualization of products is easier, and more economically viable. Customers, often non-designers, can customize products online to be printed at home, or to be delivered. These processes often rely on desktop and laptop-based software, such as Rhino with Grasshopper, and online services offered by, among others, Ponoko, Shapeways, Cubify, and Thingiverse.

Nowadays, smartphones have many features that make them suitable for use as a 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 reached the point where real-time data can be processed and used to generate three-dimensional digital models. They are also highly portable, familiar, and becoming increasingly ubiquitous.

This research builds on work carried out in the field of generative, mobile-based music, where the smartphone becomes a generic tool for creative tasks. The research explores the feasibility of allowing the generative design process to take place "on the fly", and produce 3D models that can be used to 3D print objects. It makes connections between "visualizing data" through music, "on-the-fly", in real-time, and creating forms using the mobile phone as a creative tool. It can be described as a 3D sketching process whereby 3D forms can be digitally explored, generated, manufactured, and assessed, then either discarded, or ultimately developed as finished products, in this case 3D printed vases.

Related work

Before detailing the pilot study, a brief overview of the use of mobile devices in music creation is provided, along with examples of recent 3D design apps. The choice of design task is also explained, with reference to relevant academic and creative work.

Mobile Devices and Creative Endeavors

Research into using mobile phones as musical instruments has already embraced many of the advantages of smartphones previously summarized. 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* tool maps accelerometer sensor input data and keystrokes from a mobile phone to generate and manipulate musical output in real time, "on the fly" (Essl, 2009). Oh et al (2010) describe several mobile phone music performances, among them Herrera's *interV,* where the touch-screens of iPhones are used to control music performance, and the accelerometer is the principle expressive control i.e. controlling the volume of musical notes. The reasons for using mobile phones are highlighted by Wang et al (2008), who discuss the MoPhO (Mobile Phone Orchestra), a musical group who use mobile phones as the primary instrument, in part because mobile phones are ubiquitous, portable and powerful enough to allow the creation of music anywhere (Wang, Essl, & Penttinen, 2008). Tanaka argues that by democratizing access to sensor technology, mobile phones allow for new cultural contexts for interaction (Tanaka, 2010) and new forms of expression (Tanaka, 2000).

Mobile Design Tools

While there have been a number of mobile design tools or apps introduced in recent years, the general approach differs from that of mobile music researchers. For example, Mecube

(Mecube, 2013) is a mobile app for iOS and Android that allows users to design 3D printable objects by adding or subtracting cubes. The finished objects can be saved as full color 2D or 3D files, and ordered as 3D prints directly from the app. The app claims to make 3D design easy and fun for non-designers. Sculpteo (Sculpteo, n.d.) offer an iOS app that allows users to use the touchscreen of iPhones and iPads to create customized cups (Pixel Cup) and vases (Profile Vase). The Profile Vase uses a photograph of the user's facial profile, then a rotation, to create a vase that can then be 3D printed. Autodesk123D (Autodesk, n.d.) offer a range of online and downloadable programs and apps, created to make 3D design and digital fabrication more accessible. Downloadable programs such as 123D Design and 123D Sculpt+, along with online tool Tinkercad, allow open 3D modeling and file saving for 3D printing. In contrast to these examples, we build on the approach used in mobile music creation, where mobile devices, sensor technology, and “on the fly” data processing are at the core of the creative process.

Vases as the Designed Object

As the research is to test an experimental design process in a real-world scenario, a series of objects need to be designed, and instantiated. Vases meet a number of requirements needed to fulfill the research. While they 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. The physical parameters of a miniature vase are of a workable and executable size, in terms of the size limitations of the available 3D printing technology and the costs of manufacturing. Also, miniature vases are commonly used in Taiwan to display single flower stems and therefore offer a cultural demand for such products.

Generative Vase Design

Mathematically designed vases have been created to demonstrate the validity of Birkhoff's aesthetic measure principle of fitness and function (Staudek, 1999). Reed (2013) created a series of 3D printed, rotationally symmetrical vases using MATLAB which, were similar in form to those developed by human designers. Koutsoudis et al (2009) developed a parametric vessel modeling software tool called *qp,* intended to aid the indexing of Greek vases through the extraction of their digital signatures. The authors suggest that it could be a 3D vessel modeling tool for people who are unfamiliar with 3D modeling. Again, the design process uses the curve editing and rotational symmetry of conventional CAD techniques. Similarly, Zhang and You (2002) created a series of rotational vases using fourth order partial differential equations (PDEs), their research focusing on making ornamental variations less tedious and time-consuming to model.

The 2014 Taiwan Ceramics Biennale titled "Terra-Nova: Critical Currents/Contemporary Ceramics” was held at New Taipei City Yingge Ceramics Museum. Several works demonstrating a growing interest in experimental digital design and manufacturing processes in ceramics we shown. These focused on 3D printing, interactive design processes, and parametric and generative design, all within the broader context of contemporary ceramics. The works are briefly described below.

The design collective Unfold exhibited two such works, Stratigraphic Manufactury (2012) where the same digital files were sent to different ceramic 3D printing production centers so that each printed cup was unique due to different production conditions, or errors. With L'Artisan Électronique (2010) a virtual potter's wheel allows users to create vases by passing their hand through a laser to manipulate virtual clay. The vases are saved to a database and can be 3D printed.

Jonathan Keep exhibited Icebergs (2013), a series of algorithmically generated vessels. Each vessel starts from a standard cylinder, and is "eroded" by computer code containing a random element. This produced a series of different, yet fundamentally similar forms. In his Random Growth Series (2013), a series of algorithmically generated and 3D printed vessels was produced. IN-FLEXIONS' Cutting Edges (2014) allows users to parametrically design plates on a tablet device. The plates can then be cut from clay blanks, using a CNC machine.

These were displayed in the exhibition, but they are part of a larger body of similar work. IN-FLEXIONS' own Vases#44 (2009), Studio Homunculus and Joong Han Lee's Haptic Intelligencia (2011), SHAPES iN PLAY's infObjects (2011) and Soundplotter (2013), along with Jin Hyun Park's The Vase (2014) all demonstrate that generative, 3D printed vase design is an increasing phenomenon, yet has space for the exploration of new creative processes.

Pilot Study

Aims

The described pilot study had two main aims. Firstly, it tested the overall functionality and usability of the prototype app, including uncovering areas where it could be improved in subsequent iterations. Secondly, it assessed whether vases could be designed and manufactured using the described processes, and whether they had an aesthetic style and shape that was pleasing, yet would be very difficult to design in another way.

Procedure

The study itself consisted of two parts. Part one required participants to use the prototype application to design vases during a workshop session. They then assessed their experience of using the app. Part two consisted of the designed and manufactured forms being assessed on their aesthetic qualities, by the participants.

1. Application Overview

The app works by allowing users, via movement of a smartphone, to change the shape of a basic vase, or vessel, model. This works through the capturing and processing of real-time accelerometer data. Movement on the x axis decreases (tilt forwards) or increases (tilt backwards) the number of vertical sections; movement of the y axis controls the number of twists the vase has in an anti-clockwise (tilt left) or clockwise (tilt right) direction; when used together with tilting on the the x and/or y axes, movement on the z axis increases or decreases the vertical radius of the vertical sections. Processing movement on all three axes simultaneously 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 a similar to a star with rounded end points.

The choice of accelerometer data is to enable movement of the user's hand to be measured. Often, when designing or creating form, the hand is used to draw or sculpt. The mobile phone and app are an innovative way to record, process and use this movement in real-time. The sensor data is mapped to upper and lower limits, in order to try and ensure the resulting forms are printable. Users can stop the app to view the vase form they create by pressing an on-screen *Start/Stop* button. They can then either export the model as an STL file ready for printing by pressing an on-screen *Save Vase* button or, restart the app to create further forms by pressing the *Start/Stop* button again.

2. Programming and Hardware

Processing for Android software was used to create the app. Processing is an open source Java-based programming language aimed at designers and musicians (Processing, n.d.). It allows applications to be designed, programmed and compiled for use on smartphones and tablets running the Android operating system. Apps are freely available and easily distributable. The Processing language was installed on a laptop, and used to code a series of applications for development and initial testing. The first functional iterations of the applications were then compiled to run as apps on an Android smartphone.

Mobile and smart devices develop rapidly, with the latest models having up to 4Gb RAM and quad-core CPUs. They are becoming increasingly suitable for 3D modeling, but not all users want, or can afford to buy, the latest model. With this in mind, the 3D models produced were of relatively low-resolution, and the amount of data processed was limited, to enable the app to function on mid-range, or older, Android devices. The prototype app was installed on an HTC Sensation with 768Mb RAM and a 1.2 GHz dual-core processor. The device has a number of sensors and inputs to read data from the environment, and it has an internal processor powerful enough to process the incoming data.

3. Testing the Application

To test the functionality and usability of the app, it was tested by two groups of 7 users. One group consisted of designers, the other of non-designers. For the first group, subjects were drawn from the cohort of Masters and PhD degree design students at National Chiao Tung University's Institute of Applied Arts. They consisted of 2 female and 5 male participants, with an age range of 21 to 50 years. All have experience of studying design and/or working in design or related fields, ranging from 1 to 12 years. All participants have some experience using CAD software, both 2D (Photoshop and Illustrator), and 3D (Alias, Rhino, and ProE).

The second group consisted of 2 female and 5 male participants, aged between 22 and 26. They have no background or training in design. One participant stated that they have 3 days experience using the SolidWorks 3D CAD program, but the remaining participants have no experience of using CAD. All the participants are familiar with using smartphones and apps.

During the workshop, participants were briefly told the reason for the study, the purpose of the app, and how to use it. They were allowed to familiarize themselves with the app, then asked to create vases, in real-time, derived from accelerometer data collected from the movement of the smartphone (Figure 1), and additional parameter buttons. Participant's were allowed to create three forms. These 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 favorite, to be printed.

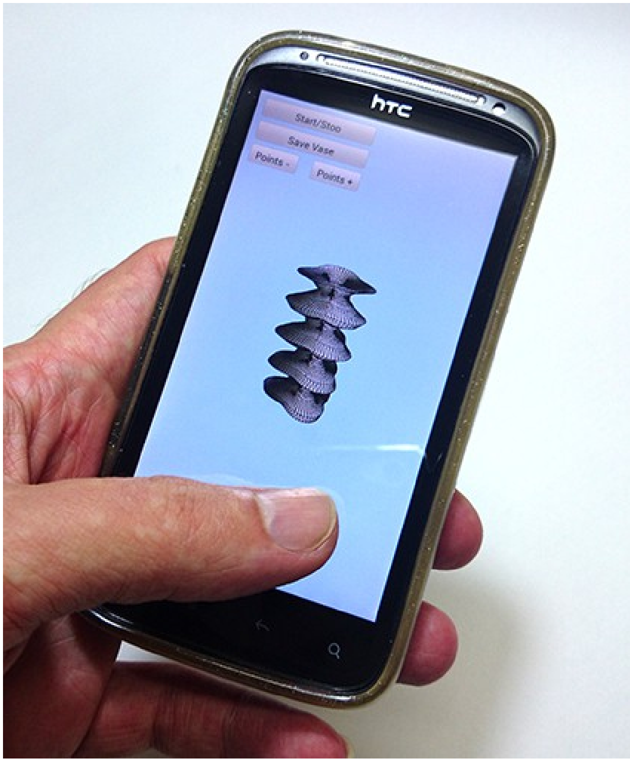

Figure **1**: Smartphone movement used to create vase design

Following this, participants were asked about their experience of using the app. A simple questionnaire was given to them immediately after they had used the app, in order to record their thoughts and feelings. Participants were also given the opportunity to offer more open comments, and expand on any feedback given, in order to improve the usability and functionality of subsequent iterations of the app.

4. Assessing the Manufactured Forms

The forms were instantiated via an Up! personal desktop Fused Deposition Modelling (FDM) additive manufacturing machine (3D printer), using white Acrylonitrile Butadiene Styrene (ABS) plastic filament material. While individual vases were considered, participants were also asked to assess the printed vases as a series of objects, based on how aesthetically pleasing they found them, and whether they offered a distinctive design language.

Results

1. Does the App Work?

From a purely technical point of view, 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.

2. Usability

Designer Group

The participants generally felt that the app was easy and fun to use, because it was simple to create a range of vase designs by moving the smartphone, and then exporting the files. One participant added that because they could use the app on a mobile device, the process was very convenient.

Non-Designer Group

Subjects thought the app's simple user interface (UI) was appealing, and the app was intuitive to use and easy to learn. They thought the app was fun to use because it makes designing objects simple, leading them to feel that they were in control of the design process. The participants believed the described process to be a new and interesting way to design objects, and found the use of sensors to control the design to be creative and unique.

One participant stated that they liked being able to design, and then have, an object they had created themselves, while another stated that it was great that it makes everyone become a designer, and you can design things you want.

3. Does This Design Process Extend Creative Possibilities?

Designer Group

Designer participants stated that they felt they were manipulating the app to design objects, rather than the app being in control. They liked that the forms were created and saved in real time.

Users with design experience stated that it did increase creative possibilities in terms of the range of forms that could be created in this particular application. Designers thought it was a good tool for creating unusual shapes, and thought it would be easy for people with no training in 3D CAD to create the form they wanted.

They felt the app would help them to be more creative because there were more possible forms than they could think of themselves. They also felt the app allowed the free creativity of organic shapes, and they liked the uncertainty of the forms it produced. They also found the range of possible forms inspiring.

Non-Designer Group

The non-designers group agreed that the app made designing objects easy. They stated that the app was simple to operate and control, so they could shape the design they wanted. As the design process does not require them to sketch or develop the forms, it was viewed as an intuitive way to design. One participant also commented that they did not even need to write computer code to acquire the form they wanted.

Five of the non-design group thought they they could design similar vases but that it would take a lot of time, possibly all day. One thought that they could maybe design something similar, whereas one was certain it would be too difficult to do.

Two of the participants said they would use this kind of app to design vases as “special gifts” for themselves or others, especially if they also owned a 3D printer. One participant commented that they would use such a tool but maybe not on a mobile phone. Another said they would use it if there were more objects that could be designed. Three participants said they would not use it because there are too few objects to choose from, the outcome is different from what they expected and, because they are not a designer, they much prefer to buy objects designed by professionals, and would.

4. Design Feedback: Comparison of Virtual and Physical

Designer Group

Designers felt their movement of the smartphone had been reflected in the printed vases, because they had managed to successfully control the design of the digital vase with their movements. However, some participants felt that the design did not completely reflect their movements, and the result was somewhat random.

Participants felt the vase forms themselves were attractive and interesting, and did have a unique design language. They also felt that they could not have designed similar vases in any other way. They liked the fact that something they had designed on a mobile device could be 3D printed. One participant said that using the app was only slightly interesting, but seeing the printed vase was exciting.

Non-Designer Group

Non-designer participants were divided on whether the printed vase corresponded to the movements used to design it. Two said that it did correspond, two said they did not remember but they liked the design anyway, while three said the printed vase did not correspond to their movements.

The non-designer group also found the printed vases interesting and unusual because each participant had created something unique by moving the smartphone differently. One non-designer liked that they could chose the vase's shape because usually they cannot.

One participant commented that the process itself is what made the vases interesting. Another offered that they resembled art from a museum rather than mere vases, whereas one commented that they were strange and ugly.

In addition, one non-designer stated that the process made them want to buy a 3D printer, and another wanted to learn more about 3D printing.

5. Suggested Areas of Improvement

Designer Group

While their reactions were generally positive, participants identified areas where the app could be improved. They felt a greater variety of forms could be offered. One participant said they had to use their imagination to envisage the forms as vases.

There were some concerns over the way the on-screen vase constantly changed shape, and some participants thought the app was too sensitive and caused the forms to change too quickly. One participant felt that they needed luck to create good forms. It was noted that the constantly changing vase forms left them feeling some control was lost, and could make it difficult to select and save the form they wanted.

One participant thought that the interface needed to be more interesting, while another suggested that when saved, the form should pop-up on the screen so they could immediately see the vase they created. Another participant stated that the app could be improved if files could be sent straight to a 3D printer for printing.

Non-Designer Group

Some of the same shortcomings were highlighted by the non-designer group. Several of them mentioned that they would prefer a broader range of forms to be available, or be able to control more parameters. One of the seven non-designer participants thought the app was not easy to use, finding it difficult to control accurately enough to create the shape they wanted. They also said that this lack of control made the app not as fun to use as it could be.

It was suggested that digital files of other objects could be imported into the app for the user to manipulate. They also suggested that a choice of different colors, patterns or textures would make the app more appealing. Most of the participants would like the app to include a way of previewing the saved objects before they are printed, rather than having to exit the app and load the exported files into an STL viewer.

One of the non-designers would like to see touchscreen control during the design process, while another would like touchscreen-controlled zoom and rotate functions to be available for previewing designs before they are exported. Another participant commented that a prompt confirming that the file had saved would be a useful addition, and also suggested that the on-screen UI buttons would be easier to use if they remained at the top of the screen as the smartphone was turned between portrait and landscape orientations.

6. Limitations of the App

In its current iteration, the app has limited functionality. Presently only vases (vessels) of a certain size can be created. The number of parameters that can be adjusted is limited to four.

Although most of the the vases printed successfully (Figures 2 and 3), others had features that were too fine to print, resulting in failed prints or incomplete vases, or prints that required additional support material that proved impossible to remove without breaking the vase (Figure 4). Printing the vases using the chosen 3D printing equipment would not be ideal if they were intended to be consumer products.

Figure **2**: Successful 3D prints (Designer Group)

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

Figure 4: Unsuccessful 3D prints

7. Suggestions for Other Uses of the App

Designers suggested that the app could be used to design perfume bottles, chess pieces, fashion accessories, chocolate, lamps, or key-chains, while non-designers suggested it could be used to design cups, plates, bowls, and home-ware accessories, cookies, gears, mechanical components, models for architecture, pens, or massage tools.

DISCUSSION

The app, and the described process as a whole, has universal appeal for both designers and non-designers, although their expectations of it are somewhat different. While the non-designer group like that the app is simple to use, and allows them to design, they require it to allow greater control over a larger range objects. They also expect the printed vases to be high quality, consumer products. The non-designers feel they have become designers, but are interested in the final outcome rather than the process itself. The designers like that it can be used as a 3D sketching tool that gives them a chance to create forms they could not easily create in another way. The designers see the app as a way of testing ideas and forms, rather than a way of designing end-use products.

CONCLUSIONS AND FUTURE WORK

The participants highlighted areas where the app itself could be improved. Firstly, if universal appeal is the aim, the app needs to meet the needs of both groups of users. Non-designers require a more developed app that allows for greater customization of a wider range of objects, and ultimately, the printing of consumer objects. While designers also want more parameters and a greater range of objects, they see it as more of a prototyping tool.

Although the focus would remain on vase (vessel) design, further iterations of the app could be developed to utilize different data sources. This would allow an even greater variety of forms to be generated. To develop a more “social” aspect of the app and the process it affords, further research could allow for collaboration between users, whereby sets of data are combined to create vases, or series of vases. The use of WiFi or Bluetooth connectivity would for example, allow the user of one smartphone to control certain parameters, and the user of a second smartphone to control different parameters, opening up the possibility of a collaborative “on the fly” design process.

The portable and almost ubiquitous nature of mobile devices means that the process of designing can be conducted at any time, and in any place. In further studies, vases for a specific room or place could be created.

Further iterations should allow a greater range of product types to be designed. Broadly, the app could be used to design vessels of all types – plates, bowls and cups – as well as vases. The app would benefit from adding more parameter controls, such as overall height and radius. Giving the user more design decisions would allow for greater individual expression in the designed forms. The sensitivity of the app needs to be reduced to make the digital form more stable as the design is being changed, and allow for more subtle variations in vessel design. In addition, re-mapping the accelerometer values to eliminate extreme forms that cannot be printed due to the creation of features that are too small, would make the design process more reliable in terms of usable output. Some of these problems could also be overcome by using 3D printers able to print objects at a higher resolution than that one used in this pilot study. Printing vases in a higher quality material would also enhance the aesthetic value of the forms.

The pilot did not directly consider the implications for the ceramic field. While design group participants have stated that the described process is of value in terms of extending shape-finding possibilities, further investigation is needed to find out if it would give ceramics designers specifically, the opportunity to do so.

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Paul D. Found is currently a PhD Candidate at the Institute of Applied Arts (IAA), National Chiao Tung University (NCTU) in Taiwan. His research is focused on the use of mobile technologies, particularly smartphones, as an aid to form-finding, shape generation, and 3D sketching. The focus is on the use of embedded sensors and 3D printing to allow "anytime, anywhere" design to take place. Currently, he is exploring the application of this idea in the field of ceramic design.

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