Digitising Traditional Cultural Designs

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ABSTRACT This paper explores a fundamental principle of digitising traditional cultural designs to introduce a model to develop a digital design tool with three levels of strategies (and five possible scenarios) for expanding traditional designs. The study structures pattern designs by analysing certain rules of traditional Korean bojagi textile designs and converting this into explicit rules in computational design. A bojagi design tool (implementing eight different schemes and allowing choice of colours and textures) was designed and implemented by the author to show the advantages of using a computational design that combines traditional principles with today's modern digital technology. The bojagi design tool that we developed was then examined by four different groups (textile/ fashion designers, merchandisers, traditional bojagi craft practitioners and random customers) in Korea. The findings resulting from the interviews suggested that the tool can successfully generate most of original bojagi designs that will be suitable for current fashion and interior markets and even extend it as a marketing (communication) and educational tool.

Keywords: Digital design; design innovation; cultural designs; Korean bojagi

Introduction

Digital technologies, tools and processes support designers, craft practitioners and marketers to visualise, collate, manipulate, and continually revise ideas with ease (Marion et al. 2012, 64; Greenhalgh 2002; Treadaway 2007, 46). Today's product development is nearly all digital in order to speed up processes, save costs for economic benefit and manifest wide colour gamuts and visual effects (Fixson and Marion 2012, 141; Treadaway 2004; Ujiie 2006, 5). Computer technology has proliferated in society and the development of computer-based tools streamlines the design and development process (Richey and Klein 2009, 21). It has been suggested that designers should expand their understanding of digital design processes and methods to create new potential designs (Parson and Campbell 2004, 88). For example, digital printing (including 3D) can create a complex set of decision points for designers and offer opportunities to expand collaborative efforts among designers, technicians and marketers from diverse disciplines (Keating and Oxman 2013, 447; Parsons and Campbell 2004, 89). Today, digital tools in the design process can also be used to build strong 'business to consumer' relationships as a marketing strategy for customisation in the fashion industry to address consumers' needs (Fiore 2008, 177; Jennings 2007, 175).

In a rapidly changing technological environment, possibilities to utilise cultural values by digitising traditional textile designs have been considered for the current fashion industry. Cultural values can give great added value in the industry as they play an increasingly important role in general fashion trends with a growth in inspiration coming from Asia (Shin et al. 2015, 195). A major concern is to maintain traditional principles and blend them with modern digital technologies to develop affordable fabrication techniques that can transfer ideas from the past to a contemporary context. As the interests of digitising designs have increased in the textile and fashion area, many studies have looked at this subject such as developing digital design processes for apparel and jacquard fabric (Parsons and Campbell 2004; Wang et al. 2012; Ng and Zhou 2009; Zhong et al. 2013), digital fabrication in architecture (Muslimin 2010), digital pattern-making for customisation (Jennings 2007; Yang et al. 2007; Fang and Ding 2008), and digital imaging on printed textiles by textile technicians (Bhakar et al. 2004), designers (Treadaway 2004; Andrew 2008), artistes (Polvinen 2005), and craft practitioners (Buechley and Perner-Wilson 2012; Treadaway 2004, 2007). However, employing such approaches is insufficient to generate an integrated paradigm with design principles, strategies and processes to develop a digital design tool based on traditional cultural designs. The evaluation procedures are also inadequate to examine the design process or

tool due to the separated studies and restricted targets. It is therefore important to construct an integrated study to develop a digital design tool for traditional cultural designs with an in-depth evaluation by diverse targets for different aspects.

The aim of this study was to explore a fundamental principle to introduce a model to develop a digital design tool based on the strategies and possible scenarios to evaluate and modify the tool. The model will be applied to traditional Korean textile bojagi designs to develop a new digital design tool which can generate the traditional pattern designs of bojagi. The software tool was designed and implemented by the authors and then examined by four different groups (textile/ fashion designers, merchandisers, traditional bojagi craft practitioners and random customers) in Korea. The results of the interviews will be used to develop later improvements of the tool and/or the underlying strategy.

A model to develop digital design tools for traditional cultural designs
In this study, a model is suggested for how a new digital design tool can be developed, evaluated and modified with three strategies and five possible scenarios. The model for digitising traditional cultural designs lies on a continuum of proceedings that begins with design characteristics of a traditional cultural design, which have been developed into a digital design tool. Investigating and analysing the traditional cultural design at the beginning is a critical step to discover their design characteristics and so to allow them to be digitsed. Three strategies will be suitable to determine a level or method to digitise the design characteristics. The design tool that is developed will then be evaluated in two phases. The first evaluation will be carried out by different groups of people to examine and identify usability and potentials of the tool. The second evaluation will be then conducted to classify a possible scenario for further modification or completion. A diagram of the model for digitising traditional cultural designs is illustrated in Figure 1 and details of the three strategies and five possible scenarios will be explained in the next sections.

The fundamental principle and three levels of strategies
Ideas to digitise traditional designs constitute an underlying concept of design innovation. Design is expressed from being a creative activity through to a strategic planning process that regulates innovation to meet market demands in increasingly competitive global markets (Cooper and Press 1995, 42). Innovation is viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs. This is accomplished through more effective products, processes,

services or technologies that are readily available to the current market and society (ibid, 43).
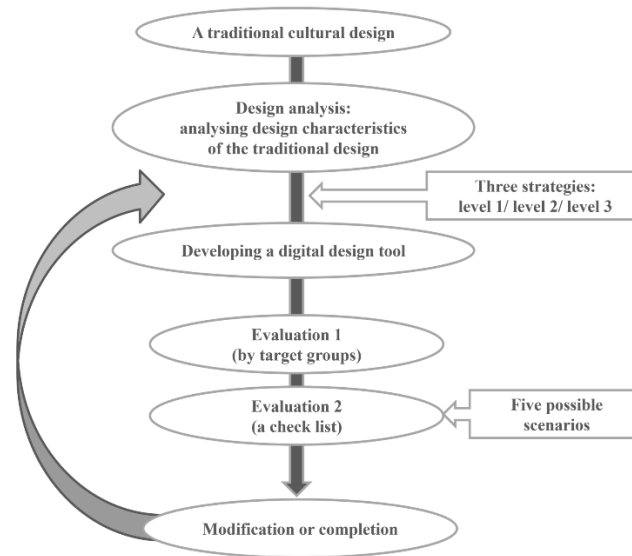
Figure 1
A model for digitalising traditional cultural designs

Design innovation can be broken down into three distinct categories. Incremental innovation generally describes the process whereby change is made through small improvements or reconfigurations which exploit existing forms or technologies, established knowledge and current organisational capabilities. Modular innovation is innovation specific to one or more components of a system and, although it may significantly change results, is not in itself radically transformative to the entire process. Conversely, radical or disruptive innovation is characterised as departing from existing knowledge, capabilities or technologies to create something new in the world. Major design innovation employs new skills, processing abilities and levels of market understanding (Best 2010, 168; McDermott and O'Connor 2002, 424).

   In this light, three strategies can be suggested for digitising traditional cultural designs as three levels of innovation. The first strategy is digitising a concept of the original cultural designs to apply it for different types of modern products. For example, a small sized bojagi (Korean traditional wrapping cloths) which was used to carry toothpicks in the past was changed to decorate USB cases in the current market. This type of design innovation will not make a huge physical change but converts the concept of the original usage or function of the traditional cultural designs into contemporary products. The second strategy is utilising digital

technologies (e.g. digital printing, scanning or computer-aided design) to digitise one of the design elements, such as patterns, colours, forms or styles, and combining these with contemporary materials. For instance, a traditional Korean trellis pattern, often used in architecture, is printed on metals sold in Korea today as name card cases. The third strategy is digitising a design system or a production method based on the current market situation as a category of radical innovation. For example, tartan has developed from its beginnings as a Highland craft to become a mass-produced, globally consumed textile using a web-interface for designing, retailing and promotion. The websites allow customers to design their own tartans; these customised tartans bring customer satisfaction as the designs they wear reflect their own individual tastes in garment choice, style, pattern and so on (Faiers 2008, 1).

The five possible scenarios
In this study, we identify five possible scenarios to classify digital tools that can be used to create traditional designs of a particular characteristic (bojagi will be used below as an example but the same ideas could be used for other traditional designs). These scenarios are useful as a way of evaluating and classifying outcomes.

In Scenario I (Complete bespoke digital design tool) the digital design tool can produce all traditional bojagi designs but no other designs. Such a tool can only produce bojagi designs and is highly desirable in that it will be easy for the users to generate bojagi designs.

In Scenario II (Incomplete bespoke digital design tool) the digital design tool cannot generate all traditional bojagi designs but can generate most of them. Although imperfect, this design tool is also desirable and easy to use. The tool described in this study falls into this scenario as will be shown later.

In Scenario III (Universal digital design tool) the digital design tool can generate all bojagi designs and many other non-bojagi designs. It can be argued that software such as Adobe Photoshop falls into this scenario. However, although such a design tool in theory is highly useful since it can generate all designs, in fact it can be less useful that Scenario II and certainly than Scenario I, because of the difficulty that the users have manipulating the tool to specifically create bojagi designs and in even knowing whether any particular design creation is a traditional bojagi design.

In Scenario IV (Partial bespoke digital design tool) the digital design tool cannot make all bojagi designs and also makes some designs that are not bojagi. Although the tool can make some bojagi designs it is less useful than the previous three scenarios.

Finally, for completeness, there is Scenario V (Inappropriate bespoke digital design tool) where the digital design tool cannot be used to generate any bojagi designs. A diagram of the five scenarios is illustrated in Table 1.

Table 1
Five Possible Scenarios

Scenario I (Complete bespoke digital design tool)	Scenario II (Incomplete bespoke digital design tool)	Scenario III (Universal digital design tool)	Scenario IV (Partial bespoke digital design tool)	Scenario V (Inappropriate bespoke digital design tool)

Traditional cultural designs   New digitised designs

Applying the model to traditional Korean bojagi textile designs

Korean wrapping cloths (bojagi) have been in use for centuries; all the surviving examples are from the Joseon dynasty (1392-1910). It had a variety of purposes, from covering a food table, draping a Confucian or Buddhist altar, wrapping a sacred text to carrying objects. It was made from fabrics that were much easier and cheaper than wood to make boxes or chests, and it had the advantage of taking up a small space due to the flexibility of a textile when it was not in use. Traditionally, the use for wrapping objects represented the individual's concern for that which was being wrapped and indicated respect for its receiver (Kim 1998; Hur 2001; Roberts and Huh 1998).

The traditional bojagi designs are investigated to analyse the design characteristics such as patterns, colours, and materials to convert into a digital design tool. The pattern types, in particular, have certain rules and can be categorised as belonging to one of four types; square type, vane type, cintamani pattern type, and free style type. Although the patterns are mainly derived from these four main categories, they can be further subdivided into six, eight or

ten types such as two different patterns of square type or two different patterns of vane type (Cho and Kim 2000; Choi et al. 2006; Choi and Eun 2004, 2005). In this study, eight pattern types (two square types, three vane types, one cintamani pattern type, and two free style types) are considered to generate traditional bojagi patterns in the digital bojagi design tool as the eight patterns cover nearly all of the subcategories.

There were five traditional Korean colours (red, blue, yellow, white and black) that are prominent in traditional bojagi designs except for some jogak-bo (free style pattern type) where diverse colours of leftover fabrics were used in patchwork form. There were also four main materials used for bojagi which were myeongju (fine silk with woven in patterns), mumyeong (cotton cloth), mosi (ramie), and sambae (hemp cloth).

As outlined in the previous section, three strategies for digitising traditional designs have been explored and the last option - digitising a design system based on current market situation - has been selected as the optimal strategy to digitise bojagi designs for a contemporary fashion and textile market. There has been current market research that a web-based digital tool will be useful for fashion product development and the early promotion for Korean bojagi (Shin et al. 2011, 222). Consequently, a digital bojagi design tool is developed with eight pattern types keeping traditional principles; five colour choices and different scales for repeating patterns are provided to allow the users to have more flexibility and a wide range of usability for designing modern fashion textiles.

Developing a digital bojagi design tool

The MATLAB 7.0.4 programme was used for developing the new digital bojagi design tool and associated graphical-user interface (GUI). MATLAB is a high-performance language for technical computing and is well-suited to a number of applications including image processing. In principle, the bojagi design tool could be written in almost any computer language that is capable of providing a graphical-user interface. However, the authors chose MATLAB because it is suitable for rapid prototyping and because we have extensive experience of using it. It is important to note, however, that other programming languages could have been used. The rationale for creating the tool was to demonstrate/implement the ideas that we have developed about bojagi designs and MATLAB was a suitable language to achieve this goal. A series of mathematical pattern types have been developed with variable parameters so that adjusting the parameters allows the users to explore the space of possible bojagi designs. The tool provides the choice of eight pattern types, any five colours and seven texture images for selection referenced by

traditional bojagi designs. It could be incorporated into current textile design systems as a pattern design system but also an effective communication tool for promotional activity. The following section deals with how the patterns are generated and gives an explanation of each of the buttons in the digital bojagi design tool.

Pattern types
The tool has been developed to generate eight pattern types of the traditional Korean bojagi; two square types, three vane types, one cintamani type and two free style types of bojagi patterns (see Table 2).

Six of the pattern types (A-F) are fixed in nature but two of them (G and H) can include random arrangements. The MATLAB tool includes a random generator for these latter two pattern types. The users can select one of the pattern types when they push the 'Pattern Type' button on the menu bar and the 'New random structure' button is only activated for patterns G and H which is one of the subcategories of 'Settings' on the menu bar. Despite the use of a random generator it is the random nature of pattern types G and H that requires the tool to be classified as Scenario II rather than Scenario I. Generating all possible bojagi patterns using a specialist tool of this nature would be almost impossible given the variety of patterns that exist in pattern types G and H.

Colour and texture selections
Five colour choices were given to users to design bojagi including a choice of border colour as a wide range of borders can be created by a traditional hand-made technique. Although traditional bojagi designs tend to use specific colours, the MATLAB tool produced only presents these colours to the user at the beginning and allows the use to freely select other colours if they so wish.
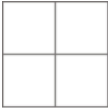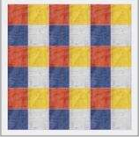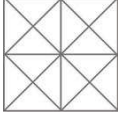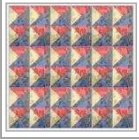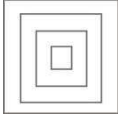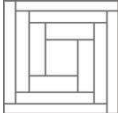
The tool provides texture images of materials (one cotton, one ramie, one fine silk without any woven patterns and four silks with different woven floral patterns) that are used for traditional bojagi designs. The materials can be selected when the users pus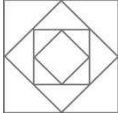h the 'Load texture' button in the subcategory of 'Settings' on the menu bar. The design tool had to incorporate texture images to allow the user to visualise and make their design choices.
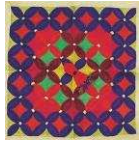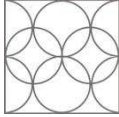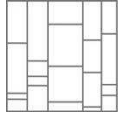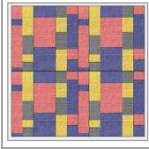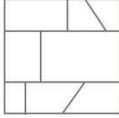
A scroll bar and other buttons on the menu bar
Repeating and scaling of patterns are one of the most important elements for textile and fashion pattern designs (Shin et al. 2015, 196). Thus, a scaling bar has been developed to generate a repeated pattern within the design tool. The scaling bar can be used to control a repeated pattern with four to thirty-six repeats of the pattern. A 'Previous design' button allows the users to return to

see their previous designs and also a border could be an option to use or remove. After finishing the design process, the designs can be saved as a JPG file format by clicking a 'Save to file' button and a 'Quit' button allows the user to exit from the tool that are in the subcategory of 'File' on the menu bar.

Table 2
Eight Types of Bojagi Patterns

Pattern types	Traditional bojagi samples (19 century)	Pattern extraction	Digital bojagi design tool
Pattern A (Square type)			
Pattern B (Square type)			
Pattern C (Vane type)			
Pattern D (Vane type)			
Pattern E (Vane type)			

Pattern F (Cintamani type)			
Pattern G (Free style type)			
Pattern H (Free style type)			
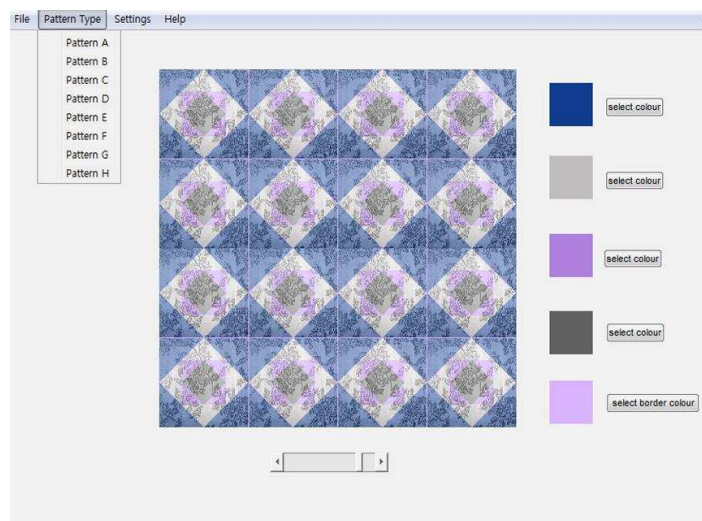
Figure 2
The Digital Bojagi Design Tool

Evaluating the digital bojagi design tool
In this study, the tool was evaluated in two phases. The first phase undertook nine in-depth interviews to assess the tool and the second phase used a check-list to identify a category of the possible scenarios based on the results of the interviews for further improvements.

Participants
Nine participants in four target groups were interviewed. The

groups were a designers group (one fashion pattern designer, one fashion textile designer and one interior designer), a merchandisers group (one VMD in industrial design area and one MD/Buyer in high-end fashion brands), a traditional craft practitioners group (two traditional bojagi practitioners) and a random customers group (two participants) in Korea. These target groups would have potentials to use the new digital bojagi design tool like a similar case of Scottish tartan design tool stated in the previous section of the fundamental principle and three levels of strategies. Therefore, the four groups were selected to collate different aspects (designers, marketing, bojagi professionals, and in general consumers points of view).

Procedure and findings

The nine interviews were conducted separately and all followed the same procedure. The interview began by giving an explanation of the digital bojagi design tool and how it can generate bojagi designs. Participants were asked to look at the tool and try to play with it before being asked to consider the tool from general perspectives of various aspects of usability and applicability. There was a list of questions for a paper-based interview guide that interviewees follow to assess the tool; general opinions of the tool, representability of the traditional bojagi designs, usability of the tool, suggestions of relevant design areas or industries that the tool may be relevant or apply to, any thoughts on the digitalisation of traditional cultural designs and other comments. The in-depth interviews allowed a deeper investigation of the tool and an identification of suggestions to improve.

According to the interviews, the representability of the traditional bojagi designs was rated highly in general. Particularly, it was pointed out that the all vane types can generate 100% of the same pattern types of traditional designs. However, one big issue was that the tool was not sufficient to visualise transparent texture of textiles naturally. The designers group stated that although the eight pattern types can generate all the same pattern types of traditional designs, it cannot create all bojagi designs as it is impossible to generate all free style pattern types.

Depending on the groups, they had different aspects for the usability of the tool. According to the designers group, the tool will be convenient for modern fashion (or interiors) textile designers to design and use bojagi patterns as it is simple to create different types of traditional bojagi patterns. However, a few issues were pointed out such as the quality of texture images and limitations to modify and combine with other design works. They also indicated that the compatibility of the tool with other textile CAD design programmes would be important for this to become an invaluable

tool widely. On the other hand, the merchandiser's group highly valued this tool as an effective marketing tool to communicate with designers and consumers (or clients). They also mentioned that the tool could be a consumer-engaged design tool as it is simple and easy to operate by any users. They particularly strongly suggested to target Western consumers or tourists as Korean consumers often have negative views about wearing traditional cultural designs (preferring more modern patterns). The traditional bojagi craft practitioners group identified that there was potential for this tool to replace the early stage of their design work such as simulating different colour combinations with different types of traditional pattern designs before a hand sewing. This group also mentioned the high possibility to use the tool for customisation. Similarly, the two random customers had positive opinions of the tool to design modernised bojagi designs (by both designers and consumers) and also to communicate between designers and consumers.

For the suggestions of relevant design areas or industries, it was recommended to use this tool for fashion product designs (e.g. scarves, bags and pouches for women's wear) and interior designs (e.g. wallpaper, table war, beddings, cushions and curtains). Also, it was suggested that the tool can be utilised in museums and galleries for cultural enhancement as experience-based entertainment. Additionally, the designers group suggested that the tool could suit industrial design area such as car interior materials, surface (with a film) designs for electronic home appliances, and billboards for public corporations. The merchandisers group proposed the provision of more information of the traditional Korean bojagi designs in the tool or combining with a current web interface related to Korean cultures. The traditional bojagi craft practitioners group indicated their concerns to use the tool in museums as an educational tool due to the limitations which cannot create all traditional bojagi designs. However, the random customers group highly recommended to use it in museums and also particular traditional villages in Korea (e.g. Bukchon, Jeonju, Gyeongju Hanoks).

According to the interviews, there were some examples using cultural designs (e.g. traditional Korean cultural styles of architecture) for modern product designs but no similar digital tools exist for traditional cultural textile designs apart from an online tartan design programme. The common thought was that digitising cultural designs is a positive idea but applying appropriate design contexts to fit into modern times maintaining the key characteristics of the traditional cultural designs would be very important. For example, it was mentioned by the majority of the participants that bojagi may not be suitable for fashion garments as people do not

like the concept of wearing cultures in Korea. Correspondingly, the merchandisers group made the point that determining the exact target and purpose will be the leading issue to be considered for developing or improving tools for digitising traditional cultural designs.

The additional suggestions from the designers were to provide different pivots to repeat patterns for a variety and to develop a mix and match pattern type. The merchandisers commented that the tool would have a big advantage to reduce production costs and providing product images with sample designs was suggested. The traditional bojagi craft practitioners suggested to modify the section of texture images to add more textile images of fine silks with woven patterns of Korean traditional patterns (e.g. ten creatures, grapes, pomegranates, arabesque patterns for wishing longevity). At the end of the interviews, they stated that the tool would be a good model balanced between cultural designs and modern technology. The random customers also mentioned that developing a digital tool would be an optimal approach to sustain traditional cultures within the contemporary market and society. They also suggested to use a previous designed pattern as a texture image to create new designs. A summary of the interviews is shown in Table 3.

The second evaluation was proving the check list to identify a category from the possible scenarios. There are five scenarios with four criteria (makes all bojagi, only makes bojagi, makes some bojagi, and makes none bojagi) to evaluate the tool based on the interviews. As the result of the interviews, the digital bojagi design tool fell into scenario II (Incomplete bespoke digital design tool) which cannot generate all traditional bojagi designs but can generate most of them as it is limited to generate all free style types of bojagi pattern designs. The five scenarios with the check list are presented in Table 4.

Table 3
The Summary of the Interviews

	Designers	Merchandisers	Traditional bojagi craft practitioners	Random customers
General opinions	• The tool is very operative for modernising bojagi pattern designs. • It will be beneficial for patterning bojagi designs as fashion textiles. • There will be a potential in interior design area to use it.	• The tool is interesting and the categories of bojagi in the tool are well structured. • It is impressive that the tool can generate bojagi pattern designs systematically.	• The tool would be convenient for designing bojagi as no automated systems exist. • The traditional way of bojagi design is time consuming as it is all hand-made. This tool can replace some manual design works such as idea sketching, colouring, matching pieces with different compositions.	• The tool will be valuable for traditional bojagi craft practitioners to design bojagi. • It will be suitable for both professional designers and consumers.
	• Nearly 95%. Especially, the pattern D generates	• More than 90%. Although it will be	• Nearly 90%. Especially, the pattern B can	• More than 80%.

Representability of the traditional bojagi designs	100% of the same pattern type of traditional bojagi. However, it is not enough to visualise transparent texture of fine textiles for jogak-bo designs. ● More than 80%. But all eight pattern types can generate 100% of the same pattern types of traditional bojagi designs. ● More than 90%. In particular, the vane pattern types and two free style types can be	essential to improve more texture images, the pattern E can generate 100% of the same pattern type of traditional bojagi designs. ● Around 90%. Particularly, the pattern D and E can generate 100% of the same pattern types of traditional bojagi designs.	generate 100% of the same pattern type of traditional bojagi designs. ● Around 85% The all vane pattern types can generate 100% of the same types of traditional bojagi designs. However, it would be limited to generate all jogak-bo designs (free style pattern types).	It will be necessary to improve more texture images. Particularly, the pattern C and D can generate 100% of the same pattern types of traditional bojagi designs. ● More than 80%. Especially, the pattern C, D and G generate 100% of the same pattern types of traditional bojagi designs. However, it would not be possible to generate all jogak-bo designs.

	100% of representability.			
Usability of the digital bojagi design tool	● In a designer's point of view, the tool will be convenient to design only bojagi patterns. The tool has a limited design variety and would be difficult to progress further design works (e.g. combining with other patterns for fashion textiles). If the tool can be compatible with current textile CAD programmes, it will be an invaluable design tool. ● It could make a big difference depends on	● The tool will be very useful for simulating design images to communicate with designers and consumers (or clients) as clients prefer a simple and easy tool. ● Unfortunately, Korean consumers have negative perceptions of traditional cultural designs. Thus, it will be better to target Western markets and customisation. ● The tool will be beneficial for designing	● It will be an invaluable tool for traditional bojagi craft practitioners. Particularly, it will be useful for an idea generation stage as simulating different colour combinations and patterns is possible before the hand sewing. ● We have had requests to design consumer's own bojagi designs and it was always difficult to communicate by hand drawings. ● Our bojagi designs are mainly based on the eight types of patterns with	● The tool will be useful for both designers and consumers to design traditional or modern bojagi pattern designs. Because the patterns are based on traditional bojagi but the colour selections and scaling function allow users to design some modern pattern designs. ● It will be an efficient tool to simulate bojagi designs for customers or clients.

	different types or quality of texture images. ● The most interesting part of this tool would be a scroll bar to create repeated patterns as it is very important in fashion and interior designs.	modernised bojagi designs for targeting tourists.	different colour selections. In that point of view, this tool fits our bojagi design process perfectly.	
Suggestions of relevant design areas or industries	● Fashion designs: dresses (a whole or a part of the designs), scarves, and bags for women's wear. ● Interior designs: wallpaper, table wear, beddings, cushions, and curtains. ● Industrial designs: car	● Fashion accessories: scarves, bags and pouches for women's wear. ● It can be used in museums and galleries for cultural enhancements as they can simulate bojagi designs and then allow	● Fashion accessories: bags and pouches for women's wear. ● Interior designs: table wear, beddings, cushions, and curtains. ● It will be great as an educational tool in museums. Although there are concerns that the tool	● Interior designs: wallpaper, table wear, beddings, curtains, and wrapping paper. ● Modernised bojagi souvenirs in particular traditional villages in Korea (e.g. Bukchon, Jeonju, Gyeongju Hanoks).

	interior materials, surface (with a film) designs for electronic home appliances, and billboards for public corporations. ● Collaborations with traditional craft practitioners could bring a synergy effect in museums. It can also be an educational tool for young people.	people to have experiences to design their own bojagi patterns.	cannot produce all traditional bojagi designs, it can be advantageous for young people to use and learn about traditional bojagi in an enjoyable way.	● The tool will be suitable for museums and the traditional villages to introduce and traditional bojagi with a video including history, techniques, and uses of the bojagi.
Any thoughts on the digitisation of traditional cultural designs	● I have seen an online Tartan design programme as a similar case and it would be a way to keep cultural designs in modern times. Also, digital	● I have not seen any similar cases. However, the most important thing will be determining an exact target and purpose. If a target group would be	● I have not seen any digital systems to translate or generate traditional cultural designs but I think that collaborations will be necessary to develop more systems or tools. It	● There are cases of modern product designs using traditional cultural styles of architecture. Although conserving cultural designs is important, it is

	programmes for knitting and weaving patterns exist. ● Culturally influenced designs are always one of the fashion trends so that developing digital design tools will be worthwhile. ● There are some cases using traditional cultural styles of architecture for modern product designs. If digitised cultural designs could fit into modern contexts, that would be excellent.	designers, it is necessary to improve more options for varieties. On the other hand, if a target group would be general people for an educational tool in museums or galleries, a new web interface or video should be created first and then combining with the current tool for simulations. ● Digitising cultural designs is a positive idea in general but you should be careful to apply it for fashion	is important to keep traditional cultures but it has to be reinterpreted to fit into modern times. ● Modernising traditional cultural designs with key characteristics and then let people use it in daily lives is the direction to go.	necessary to manipulate it for modern design contexts. Thus, developing a tool would be an optimal approach to sustain traditional cultures within the contemporary market and society.

		garments as people do not like the concept of wearing cultures in Korea.		
Other comments	● Compatibility of the tool will be a main issue to use it widely. ● The tool must provide different pivots to repeat patterns for fashion and textile designers. ● It will be interesting to develop a mix and match pattern type with the eight patterns. ● If users can control the size of the pieces, it will be more attractive for designers.	● The tool will have an advantage to reduce production costs as hand-made is the traditional method. ● If you can add more information of traditional bojagi, it would be an interactive marketing tool to learn and design bojagi. ● It will be helpful to produce examples of the end product design images.	● This tool will be a good model balanced between cultural designs and modern technology. ● I would like to suggest to add textile images of woven fine silks patterns with Korean traditional patterns (e.g. ten creatures, grapes, pomegranates, arabesque patterns for wishing longevity).	● The tool will be more useful to design modernised bojagi designs for contemporary interior markets. ● It will be interesting to use a previous designed pattern as a texture image.

Table 4
Categorisation of Digital Design Tools (using bojagi as an example)

	Scenario I (Complete bespoke)	Scenario II (Incomplete bespoke)	Scenario III (Universal)	Scenario IV (Partial bespoke)	Scenario V (Inappropriate)
Makes **all** bojagi designs	O		O		
Only makes bojagi designs	O	O			
Makes **some** bojagi designs	O	O	O	O	
Makes **none** bojagi designs			O	O	O

Figure 3
Bojagi samples in different scenarios (scenario I: a, scenario II: b, scenario III: a+b+c, scenario IV: c and scenario V:c-a)

The four potential routes were subsequently considered to improve the tool after the two phases of evaluation. For the first route targeting designers, we can provide more texture images and different repeat patterns. It is also able to modify the type of file format (TIFF or JPEG) to save designs and then designers can open and manipulate the design files with any current design software for further design process. For the second route targeting consumers as a marketing tool, we can create a new button to provide sample images of end product designs for effective communication. For the third route targeting traditional craft practitioners, modifying the 'Load texture' section is possible to add the traditional Korean patterns (e.g. ten creatures, grapes, pomegranates, arabesque patterns for wishing longevity) or cultural styles from other areas (e.g. architecture). For the last route targeting museums or galleries, it will be possible to provide more information of the traditional Korean bojagi by modifying the 'About' button in the subcategory of 'Help' on the menu bar.

Conclusions
This study introduced a model to develop a digital design tool with three strategies to expand the traditional cultural designs and five possible scenarios for evaluation. The focus of the study was exploring an integrated paradigm to digitise traditional cultural

designs with design principles, strategies and processes. Two phases for evaluation were explored to examine and improve the tool.

The model was applied to traditional Korean bojagi designs to develop a new tool which can produce eight types of patterns, any five colour selections, and seven texture images by analysing traditional Korean bojagi designs and converting them into computational design. The tool was examined by four different groups (three textile/ fashion designers, two merchandisers, two traditional bojagi craft practitioners and two random customers) in Korea and the nine participants were asked to assess the representability and usability of the tool, the design areas or industries that the tool may be relevant or apply to, general thoughts on the digitisation of traditional cultural designs and other comments. The results of interviews were used to determine one of the scenarios to improve the tool and the strategy.

The findings from the interviews indicated that there is huge potential to utilise the tool as a design tool, an interactive marketing tool (or a communication tool), or an educational tool in different areas. The second phase of evaluation showed that the tool fell into the scenario II (Incomplete bespoke digital design tool) which cannot generate all traditional bojagi designs but can generate most of them. There is currently no automated method that designers (or any users) can use to generate only bojagi designs. It is therefore potentially valuable for designers and consumers for customisation and reducing the production costs as hand-made is the traditional method. It was also pointed out that digitised designs created using this tool are referred to as modernised cultural designs which have both cultural features and commercial values, therefore allowing these designs to fit into contemporary markets. However, the participants agreed that digitising cultural designs is an approach which must be further developed but applying it to appropriate modern design contexts containing the central characteristics of the cultural designs will be a main issue. The interviews revealed that depending on compatibility with current CAD programmes, this can be an invaluable design tool for designers and also manufacturers of design software would be interested in being able to incorporate this new tool into their commercial systems.

As with all research, limitations must be considered and there will be avenues in which future work can be carried out to further modify more about the tool. The four potential routes to improve the tool depending on the targets and purposes were described in the previous section. The same method of evaluation can be followed after the modifications. Also, future work might involve the development of a commercially available bojagi design tool and

that would probably require other computing languages; for example, java and xcode could be used to create Android or IoS apps respectively. Another future research direction will be studying consumer perceptions of cultural designs or products. Consumers could have different perceptions (or views) of traditional cultural designs for different categories (e.g. fashion, architecture, art and paintings) or different countries' consumers having different aspects for cultural designs.

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