Application Research of 3D Printing Technology on Dress Forms

Hye-Won Lim, Tom Cassidy, and Tracy Diane Cassidy

***Abstract*—A dress form is an essential tool in the clothing-making process for pattern block development, draping and quality inspection. However, it is noted that a single dress form is not applicable for a large variety of body shapes. Adjustable dress forms are readily available and some make their own custom-made dress forms in an attempt to make up for the insufficiency of conventional dress forms. However, such types of dress forms are rather costly and their effectiveness is debatable. With this is mind, a customised adjustable kit for the dress form was developed, with the aim to cover different body sizes and shapes more precisely. The kit adopts 3D printing technology which enables generating and changing the shape of components efficiently.**

***Index Terms*—3D printing, adjustable dress form, body shape, dress form, padding.**

I. Introduction

In general, most fashion companies use dress forms throughout the different stages of the clothing manufacturing process; such as pattern block development, draping and quality inspection and the dress form manufacturers have attempted to produce advanced and functional dress forms to better suit their customers' needs [1]. However, the differences in body shapes and sizes are distinctive and the special needs for specific body types cannot as yet be produced economically [1]. Nowadays, 3D printing technology which helps to realize any creative idea become a reality at affordable prices and promptly is becoming more popular [2].

The purpose of this study was to conduct an experiment to develop a prototype for customizing an adjustable padding kit using a 3D printer and following a DRM (Design Research Methodology).

II. Background

A dress form is defined as "a replica of a human form made of cloth, padded and mounted on a metal base that is used for draping and fitting garments" [2]. One definition of a dress form is: "An adjustable dummy used in dressmaking that can be made to conform to a person's figure" [3]. A dress form which is also called a dummy, a dress stand, a body form, a model form or a figure is a basic requirement in the clothing manufacturing process and is used for pattern block development, draping and quality inspection [1].

Materials for a base shell and a covering are significant parts of the dress form. Lightweight and reinforced plastics, wire, wood, and a solid cast have been used for the base shell [4]-[6]. The covering materials used include foam, stretch and machine-knitted fabric, high quality canvas, cotton, linen, and hemp fabric [4]-[6]. Kennett & Lindsell Ltd., UK, use glass reinforced polyester for the base with a layer of padding and a linen covering on the exterior. Siegel & Stockman France, and the Wolf dress form factory, USA, use a papier mâché shell with a linen covering.

Historically dress forms have developed while adapting to constantly changeable fashions and modified in shape and measurement to satisfy the demands of silhouette changes [7]. The dress form manufacturers have considered how to develop enhanced and functional dress forms to satisfy mass production processes but also they have to meet special needs for specific body types and clothes for a better fit [1]. One such type of adjustable dress form uses modules of shape. This modular type was developed by Singer Direct® having twelve dials to adjust the sizes to a person's requirements by tightening or loosening a dial (Fig. 1) [8]. A second type of adjustable dress form is the padding type, 'Uniquely You' which is a pre-shaped adjustable dress form made of a high-density soft polyurethane known as foam rubber as it can be squeezed and reshaped easily (Fig. 2) [9].

Fig. 1. Adjustable dress forms manufactured by singer direct®.

Fig. 2. 'Uniquely you'.

Adjustable dress forms enable different sizes to be produced to fit a diverse range of body shapes which helps

Manuscript received November 16, 2015; revised January 17, 2016.

Hye-Won Lim is School of Design, University of Leeds, UK. LS2 9JT (e-mail: sd10hwl@leeds.ac.uk).

Thomas Cassidy is with the University of Leeds and a Fellow of the Design Research Society (e-mail: T.Cassidy@leeds.ac.uk)

Tracy Diane Cassidy is with the University of Huddersfield and the Textiles Thinking Research Center leader (e-mail: T.D.Cassidy@hud.ac.uk)

DOI: 10.7763/IJET.2017.V9.949

customers who do not conform to the standard measurement sizes of mass manufactured dress forms. However, to measure and produce the exact size and shape is not an easy task for many.

Fabulous Fit® U.S.A. produce a fitting solution kit by inserting molded pads under dress form covers to duplicate the required size and shape (Fig. 3) [10]. The manual padding of the dress form is still the most popular method used to correct the size issue but this process is time consuming and laborious (Fig. 4) [11], [12].

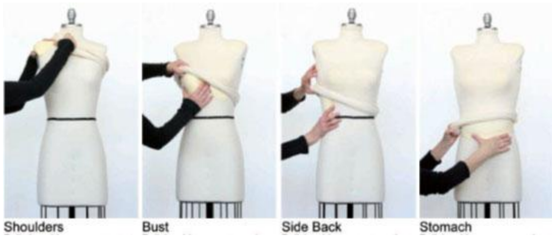

Fig. 3. Customising padding kits.


Fig. 4. Padding with manual method.

Since the late 1990s, some dress form companies began to use 3D body scanners for particular needs. For example, ‘Shapely Shadow’ and ‘Alvanon’ manufacture customized dress forms for certain brands or a fitting model’s measurement sizes using a 3D body scanner. 3D body scanning helps to capture a specific body image to develop a dress form which is perfectly and accurately matched for the needs of garment designers, clothing manufacturers, and retailers [13]. However, this 3D scanning technology for customized dress forms is difficult to access by general customers due to the high prices and the special knowledge and experience that is required to use the machine.

The emerging technologies, 3D scanning and 3D printing can help to create any design and shape quickly and efficiently [14]. 3D printing technology can also help to save time and money because 3D printing uses fewer raw materials than a CNC (computer numerical control) machine and can print only the necessary parts [14]. In addition, 3D printing allows any factory to produce the same quality products if they have the same raw materials and blueprints and it helps to save shipping charges in the export trade [15].

With the help of 3D printing technology, architects, artists, and designers can create unique and complicated shapes of their own design without any limitations. [15]. Fashion design is one of the potential areas to optimize 3D printing techniques and 3D printing technology can be adopted into the fashion design field in two areas; 3D printed fabrication and 3D printed clothing construction. The principle of 3D printed fabric is a combination of each unit or digitalized weaving using calculations and the combinations of algorithms and patterns generated by formulas that can create extensive three dimensional forms including fractal dimensions [16] (see Fig. 5).

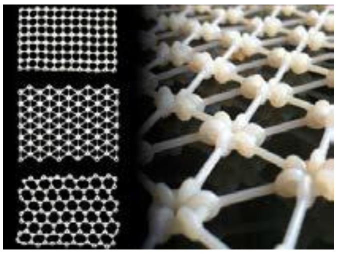
Fig. 5. 3D printed fabrics.

3D printed clothing is also divided into two types which are a combination of units and creations of the intended shape based on the designer’s ideas and inspirations. Fully wearable clothing was developed by XYZ Workshop which is a combination of a floral motif of mesh panels using flexible PLA [17]. Their dress was designed based on the 3D scanned torso for fitting onto the body (see the left of Fig. 6) [17]. 3D printing designer, Iris van Herpen created her unique design using 3D printing technology and observed that “3D prints finally act with the movement of the body” and “Everybody could have their body scanned and order clothes that fit perfectly” (see the right of Fig. 6) [18].


Fig. 6. 3D printed clothing: XYZ Workshop (left) and Iris van Herpen (right).

III. Materials

The dress form used in this study is a half-scaled (1/2) body or mini body. The material of the dress form is urethane foam sufficiently soft for pinning a hemp fabric covering onto it. The dress form in this study represents the half scale size 55 which is one of the Korean women’s clothing sizes. The actual sizes of the dress forms which are followed are; shoulder length- 5.7cm, bust- 43cm, waist- 33cm, hip- 45.5cm, and the total body length- 41.5cm [19].

The prototyping was conducted using a ‘3D Systems Delivers Sense Consumer 3D Scanner’ (by ‘3D systems’ USA) [20]. This 3D scanner is a hand-held portable type which can scan a minimum of 0.2m×0.2m×0.2m to maximum 3m×3m×3m.

The 3D printer was a ‘3Dison Multi’, manufactured by ‘Rokit’ South Korea [21]. The printer is an extruder type that uses the printing method FFF (Fused Filament Fabrication); a filament is melted at high temperatures and is layered continuously to generate the required shape. There are two extruders (0.4mm and 0.6mm) with a hot end nozzle. A 0.4mm nozzle was chosen for the PLA (Poly Lactic Acid) filament with a 0.02mm tolerance as an experimental material due to cost and accessibility for this study.

IV. Methods

Design research is a rapidly growing field of study having substantial importance to develop products and to improve the quality of design solutions and outputs [22]. According to Design Research Methodology (DRM), there are four stages to develop solution suggestions: Research Clarification, Descriptive Study I, Prescriptive Study and Descriptive Study II (see Fig. 7) [22]. DRM emphasizes that a better understanding of the current situation is necessary to determine the influencing criteria and requirements to complete the practical outcomes of the project [22].

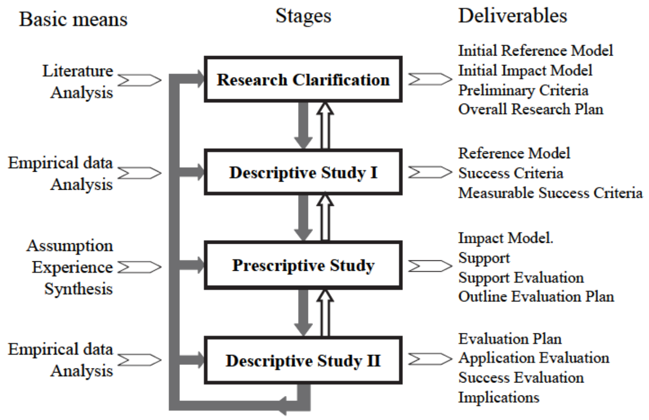

Fig. 7. DRM framework: stages, basic means and deliverables.

In the Research Clarification (RC) stage, the current materials for dress forms and industrial developments which have attempted to minimize the defects were explored to set the overall research aims which were described at the introduction. The current understanding of requirements and insufficient adaptability of current manufactured dress forms were revealed from the literature. Improved and supportive designs which could compensate for the defects of current dress forms were determined in the Descriptive Study I (DS-I) stage. To enhance the current manufactured dress form drawbacks such as unified sizes and shapes, the adjustable components were designed for the diverse customers' varying shapes. The body shape classification by Rasband was adopted to create a representative group of customers and the 3D printer was chosen for developing the component supports because of its accuracy and flexibility [23]. Prescriptive Study (PS) for developing supports in a systematic approach with consideration of the DS I results was followed. The practical outcomes of adjustable padding kits were produced using the 3D printer after 3D scanning and modeling. Finally, Descriptive Study II (DS-II) was conducted to evaluate the supports' accuracy and suitability based on the criteria developed at the earlier stage.

V. Design Process

The development process of the customized adjustable kit was planned in five stages; 'idea design'- '3D scanning of the dress form' - '3D modeling of the kits'- '3D printing of the developments' - 'post processing' (see Fig. 9). It has been shown that the 3D printing technology's three main phases are modeling, printing and the finishing of the product [23], however, two earlier phases for adjusting the idea were considered in this study.

The customized adjustable kit was designed to create a wider or larger size or shape than the fixed sized dress forms; though it is impossible to decrease the sizes of a dress form below its set limitations.

First, the experimental shapes for the adjusting body parts were selected to create a specific body shape according to the body shape classification by Rasband (see Fig. 8). Rasband classified the female body into six different shapes; 'Triangle shape', 'Inverted triangle shape', 'Rectangle shape', 'Hourglass shape', 'Diamond shape', and 'Rounded shape' [24].

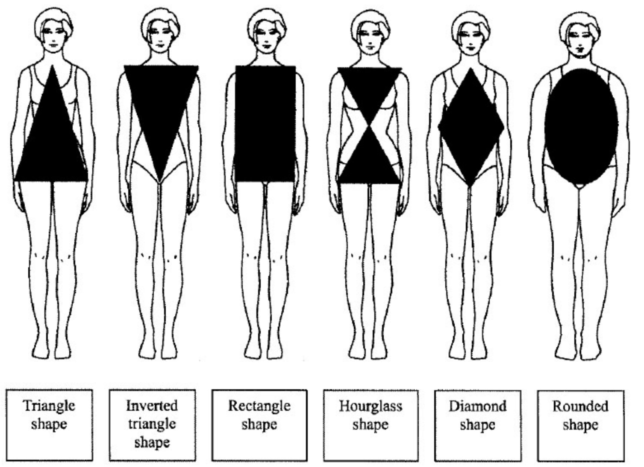

Fig. 8. Classification of body shapes by rasband.

In this study, only the components for creating four of Rasband's body types were chosen (1. Inverted triangle shape, 4. Triangle shape, 6. Hourglass shape, 7. Rectangle shape) and additional body shapes with wider waist, protruding bust and hip were then developed to include body type numbers 2, 3 and 5 (see Table I). The added amounts for each part were 1-2cm. However, the size of each circumference was divided by two excluding the shoulder length as the components were developed only for the right side following the manual padding method.

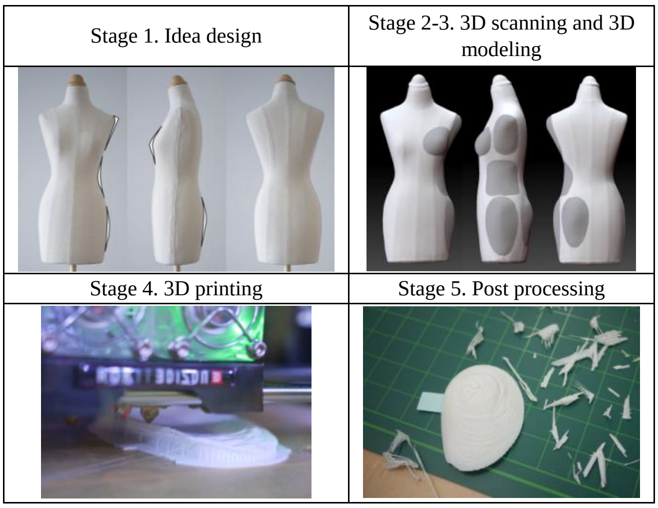

Fig. 9. Customized adjustable kit development process.

Secondly, the experimental dress form was 3D scanned. When the dress form was in focus, the 3D scanner was moved around the dress form. 3D scanned images were captured several times and the images were merged to create one complete image. After generating the scanned image of the dress form, the surfaces of the image were modified to cover the gap in the meshes.

TABLE I: ORIGINAL SIZES, ADDED AMOUNTS, AND INTENDED SHAPE OF THE DRESS FORM

	Body Parts	Original Size	Added Amounts	Intended shape
1	Shoulder Length	5.7cm	1cm	Inverted triangle shape*
2	Bust/2	21.5cm	1cm	Protruding bust
3	Waist/2	16.5cm	1cm	Wider Waist
4	Side hip/2	22.5cm	1cm	Triangle shape*
5	Hip/2	22.5cm	2cm	Protruding hip
6	Shoulder + Hip/2	9.25cm/ 22.5cm	1cm/2cm	Hourglass shape*
7	Waist + Side Hip/2	16cm/22.5cm	1cm/1cm	Rectangle shape*

Thirdly, the shape of each component was developed into 3D CAD images using the 3D CAD program, ‘Z Brush’. The original scanned images were copied as a new layer of skin and the only layers of the intended shapes were extracted from the original images. Next, each added amount was applied to the extracted layers and the overall shapes were trimmed to combine the dress form. The offset 3D images outlines were trimmed smoother and thinner to fit the experimental dress form without any gaps.

Finally, the generated 3D CAD files consisting of cross-sections were entered into the 3D printer. Some options such as the layer height, thickness, infill percentage, printing speed, raft and supports were also set. Each cross sectional layer was accumulated layer by layer and, after printing all of the layers from the images the 3D printing developments were produced. In this study, one side of component was developed because the draping and padding were conducted on only half of the dress form to save time and effort (see Fig. 4) [12].

Lastly, some extra supports of 3D printing outcomes were removed and surfaces were trimmed smoothly using an emery cloth. The 3D printed padding kit was attached to the dress form using double-sided adhesive tapes. As with manual padding methods, the adjustable kits were attached at the right side.

VI. RESULTS

The developed components of the customized adjustable kit are shown on the Fig. 10. Based on the design process stages from DRM, the DS-II stage needed to focus on the evaluation of the supports. The evaluation was conducted by measuring whether the added amounts were adopted onto each component and the intended shapes were produced properly and accurately. The overall shapes of all components were produced the same as those intended. There was a subtle gap between the components and the dress form around the edges even though the nozzle size of the experimental 3D printer was only 0.4cm.

For the evaluation of the accurate size and shape generations, first, the center and back front lines were marked onto the dress form to divide each side while checking each side division was the same. The measurement of each of the body parts were followed using the dress form measurement method given by Armstrong: ‘Shoulder length- Measurement from the shoulder-neck to the shoulder tip, Bust circumference- Across bust and full back (with tape held parallel to floor), Waist circumference- Around waist line, Hip circumference: Measurement around the widest part of the hip (with tape held parallel to floor) [7]. The half measurement sizes of the original dress form were compared with the sizes after the components were applied (see Fig 11).

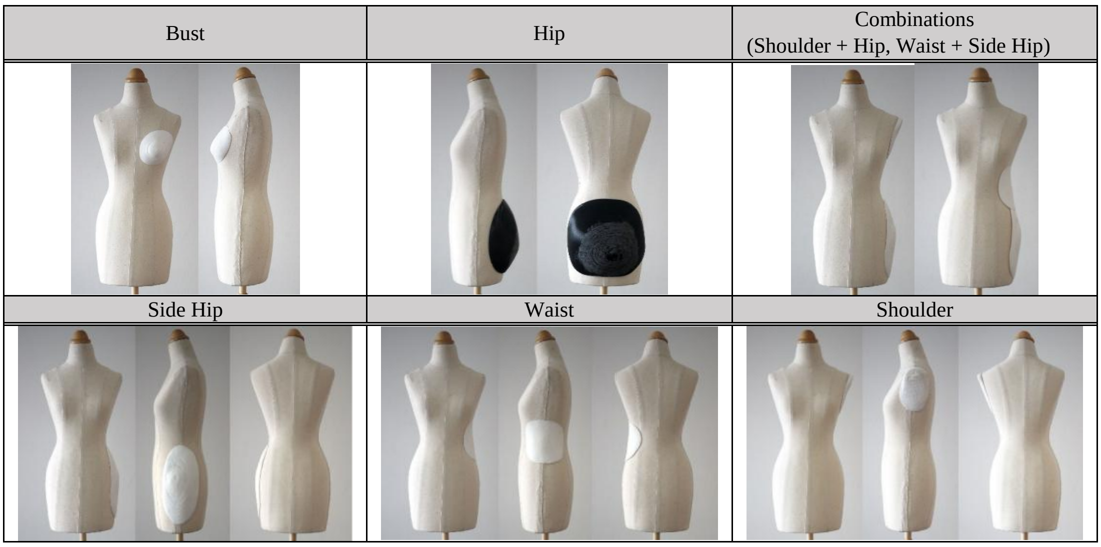

Fig. 10. Adjustable padding kit development.

In total, the outcomes of the 3D printing were convincing in consideration of the experiment. The measurements of each components were printed with minor differences when these are compared with the idea design shown on the screen of the 3D CAD program (see Table II). The accuracy of the outcomes can be said to be acceptable because the intended shapes were created and merged properly onto the dress form. However, the tolerance average of the industry is 0.2mm and the FFF type of 3D printer's tolerance ranges from 0.05mm to 0.5mm [25].

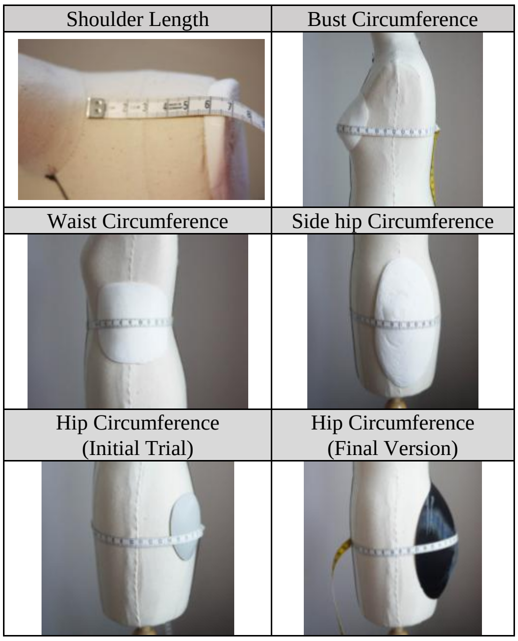

Fig 11. Customized adjustable kit evaluation.

TABLE II: ORIGINAL SIZES AND THE SIZES WITH COMPONENTS

Body Parts	Original Size	Intended sizes	Size with components
Shoulder Length	5.7cm	6.7cm	**6.7cm**
Bust/2	21.5cm	22.5cm	**22.2cm**
Waist/2	16.5cm	17.5cm	**17.6cm**
Side hip/2	22.5cm	23.5cm	**23.2cm**
Hip/2	22.5cm	24.5cm	**24.5cm**

In the case of the material of the development, the components were too stiff for pinning which is required when design a garment on a dress form but this issue was expected at the idea design stage. A manufactured dress form cover with a soft foam layer can be used as a dress form cover and the thickness of the cover also can be calculated at the 3D modelling stage. In a further study, the accuracy and suitability are to be increased by adopting the size differences. Moreover, further sizes will be tested to develop more diverse shapes and sizes and which will be evaluated by dress form users.

VII. CONCLUSIONS

In this study, an experiment of developing an adjustable padding kit was conducted for the precise duplication of a specific body shape using 3D scanning, 3D modelling and 3D printing technology. It was found that the applicability and effectiveness of developments of an adjustable padding kit has the potential to be adopted due to its size accuracy and convenience if issues such as the ability to pin to the dress form were addressed. It was also found to be easy to produce any adjustable body part for a dress form and the thickness can also be changed easily when 3D scanned images were used. This study can be extended to apply to other materials and other body parts

VIII. LIMITATIONS

Only small range of size variations were used at this stage and are to be verified through a further evaluation process by dress form users. Therefore the findings cannot be generalized at this stage, a limitation that is to be addressed in the next stage of the research.

REFERENCES

[1] Y. Hyun and B. J. Shim, "A basic study for the development of educational dress forms for male adults -survey of male dress forms for men's apparel company and the education for men's wear in fashion dept. of university," *Journal of Fashion Business*, vol. 8. no. 1, pp. 100-114, 2004.

[2] A. Joanne and F. Sterlacci, *Historical Dictionary of the Fashion Industry*, Scarecrow Press, 2007.

[3] Collins English dictionary — Complete and unabridged harper collins publishers. [Online]. Available: http://www.thefreedictionary.com/_/misc/HarperCollinsProducts.aspx?

[4] D. Shackell, *Accent on Sewing*, London: Mills & Boon, 1967.

[5] N. Hollis, *Successful Sewing: A Modern Guide*, London: Faber, 1969.

[6] H. Stanley, *Flat Pattern Cutting and Modelling for Fashion*, Leckhampton: Stanley Thornes, 1991.

[7] H. J. Armstrong, *Draping for Apparel Design*, New York: Fairchild; Oxford, 2008.

[8] Singer direct. [Online]. Available: http://www.singerdirect.co.uk/

[9] Uniquely you. [Online]. Available: http://www.allbrands.com/products/3900-uniquely-you-pinable-foam-dress-form-customize-cot

[10] Fabulous fit®. [Online]. Available: https://www.fabulousfit.com/

[11] E. Kopp, V. Rolfo, and B. Zelin, *How to Draft Basic Patterns*, New York: Fairchild Fashion & Merchandising Group, 1991.

[12] S. P. Stern. *Padding a Dress Form*. [Online]. Available: http://www.threadsmagazine.com/item/22940/padding-a-dress-form

[13] A. Joanne and S. Francesca, *The A to Z of the Fashion Industry (The A to Z Guide Series)*. Scarecrow Press, 96th revised edition, 2009.

[14] B. J. Park and Y. S. Nam. (August 2013). *The Patent of the 3D Printer Can Print Anything is Expired in Early of 2014*. Hankyung. [Online]. Available: http://www.hankyung.com/

[15] H. Lipson and M. Kuman, *Fabricated: The New World of 3D Printing*, Indianapolis: John Wiley & Sons, 2013.

[16] Scrawford. (May 2011). *3D Printing Flexible Grids*. [Online]. Available: http://lmnarchitects.com/tech-studio/fabrication/printed-flexgrids/

[17] XYZ workshop. [Online]. Available: http://www.xyzworkshop.com/

[18] Iris van Herpen uses 3D printing and magnets to form Spring Summer 2015 fashion collection. (October 2014). [Online]. Available: http://www.dezeen.com/?p=557546

[19] Mannequin world. [Online]. Available: http://www.mnqworld.com/

[20] 3D systems delivers sense consumer 3D scanner. [Online]. Available: http://www.3dsystems.com/

[21] 3Dison multi 3D printer. [Online]. Available: http://en.3disonprinter.com/

[22] L. T. M. Blessing and A. Chakrabarti, *DRM, A Design Research Methodology I*, Springer, 2009.

[23] A. P îjan and D. Petrosanu. "The impact of 3D printing technology on the society and economy," *Journal of Information Systems & Operations Management*, pp. 1-11, 2013.

[24] M. -E. Faust, S. Carrier, and P. Baptiste. "Variations in canadian women's ready-to-wear standard sizes," *Journal of Fashion Marketing and Management*, vol. 10, no. 1, pp. 71-83, 2006.

[25] SD3D - FFF VS. Sla VS. SLS: 3D printing. [Online]. Available: http://www.sd3d.com/

Hye-Won Lim is a PhD student in School of design at the University of Leeds, UK from 2013. She obtained her MA degree in fashion design from the same school in 2011 and she had acquired BSc degree in clothing and textiles from the Chonbuk National University, South Korea. She worked as a part-time lecturer teaching clothing construction, draping, and tailoring from 2006 to 2008 in South Korea. She also worked as a clothing CAD pattern developer in Seoul, South Korea before joining the University of Leeds. Her research interests are pattern making and clothing construction. She is currently studying about human body shape analysis and clothing sizing systems.

Tom Cassidy holds the chair of design in the University of Leeds. He holds four degrees (ATI, MSc, MBA and PhD) and is a fellow of the Design Research Society (FRDS). He has carried out many consultancies, both nationally and internationally since the late 1970s, for agencies such as the UN, ODA and Hong Kong Polytechnic University. Professor Cassidy is a regular reviewer for the Textile Research Journal, Measurement Science and Technology, the Journal of the Textile Institute and many other academic journals. He has published over thirty journal papers, 25 conference papers, co-authored one book and published 5 chapters in books.

Tracy Diane Cassidy is a reader in fashion & textiles, at the University of Huddersfield. She obtained her PhD through the investigation of Colour forecasting at the De Monfort University, UK. Tracy is the first author of the book *Colour Forecasting* (Blackwell) and has published more extensively in other areas of fashion marketing and fashion and textile design. She is an established author with international presence, a reviewer for many reputable journals, and editorial board member. She recently trained as a master upholsterer using both modern and traditional materials and techniques.