Smart Swimsuit Design for Taiwanese National Athletes

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Abstract
The aim of the research is to develop a smart swimsuit for Taiwanese national athletes. The research utilizes a wearable electronic device to monitor the Mechanomyography (MMG) muscle data of swimmers, to construct smart swimwear in real time. The athlete, coaching team and medical team are able to read the muscle date patterns of athletes easily. The research investigates the smart swimsuit applying four steps. Firstly, the author interviewed swimmers to collect key data relating to the problems with existing swimwear in the context of competitive sports. Secondly, after developing a fashion illustration and completing a technical drawing of the garment, the athlete was interviewed to adjust the garment design. Thirdly, the research takes a hands on approach to production; applying laser cutting technology, waterproof heat transfer film, and invention patent No. I1621405 for a 3D sculpturing garment manufacturing method and system to construct the cloth. The final step involves the athlete wearing the garment and giving feedback about the fitting. The feedback was used to refine the design and align the swimsuit with the wearers' needs. The research solves the fitting and water drag problem with existing swimsuits by systematizing the fashion design procedure mathematically. In summary, this study focusses on developing a swimsuit for Taiwan national athletes wishing to engage in competitive sports. It also demonstrated that a well-designed smart swimsuit has a high degree of pattern fitting. This made it possible to visualize the muscle data of athletes to complete further training.

Keywords: Smart Clothing, Pattern-making, swimsuit, Athlete.

Introduction

Based on a bright result of Taiwan team in 2017 Summer Universiade, the Ministry of Science and Technology lunches 24,000,000NTD founding to support precision sports science research in 2018. There are three main tasks of investigation, including transportation training, physical recovery and injury prevention, technical and tactical analysis. These are going to improve athletic performance, enhancing the physical and metal prevention of athletes, assisting coaches and athletes in sports decision-making. This research is investigated on intelligent training of sports science to construct smart swimsuit to monitor the biomechanical performance athletes.

- **Aims and objective**

The research aim is to develop customized athletic sportswear for professional swimmers. The objective is to improve the fit of the swimsuit and develop the pattern to create a smart swimsuit. The coaching team is able to monitor the biomechanical data from the swimmer via the smart performance wear, to then direct the individual on how to improve their performance.

Literature Review

(I.) Smart Clothing Design

Ariyatum, Holland, Harrison and Kazi (2010) the development of smart clothing in 1990s was mainly researching and developing by military use, such as U.S.A and European Union. These innovation research and development (R&D) investigates on the develop Smart clothing. Since 2001, many international sports brands are developing their produce with sensor and device, such as self-adapting shoes of Adidas, FM radio shirt of Gapkid, MD & AMP jacket of Burton's and self-heating jacket of North Face. In 2005, more smart apparel products were developed in fashion, such as Levis's iPod jeans, Zegna's Bluetooth jacket and Thai solar jacket, and Oakley's solar clothing. In March 2018, Taiwan Smart Textile Alliance was established with a total of 41 industry participants from local industry. There are six smart clothing companies to exhibit on Computex 2018 June. These smart clothing are designed for sleepwear, bicycle riding and a variety propose of electronic textiles such as smart clothes with virtual reality (VR) games.

A interview result of Jung, Kwak, Park, Lee (2017) from south Korea showed that gym users are looking for MMG sensor to collect body data from wearing smart clothing and to do gym activities.

(II.) Sports Science of Swimming

Since1980s, many famous physical education universities use kinesiology, exercise and sport science to do competitive athletes research (Wu, 2016) such as using biomechanics to study high jumpers（Lee, 2010）、basketball（Lin, 2017）、Track and Field （Ko, 2019）、Boxing（Chang, 2018）、table tennis（Wu, 2019）、yoga posture（Liu, 2017）.

Adopting biomechanics to elite swimmer training is a science base study to take talents to athletes. Take the research of Liang (2001) for example, he studied Methods to do Competitive Swimming Training. The research of Hung（2013）was to do coaching by

Systematic Scientific Training. Lien（2013）designed machine to help freestyle swimmers. Lee（2016）gained parameters from Triathlon race. Chen（2018）studied the relationship between freestyle swimming lower limb performance and its professional skills.

(III.) Textiles of Completive Swimsuit

In 2017, The Federation Internationale de Natation (FINA) publishes FINA REQUIREMENTS FOR SWIMWEAR APPROVAL (FRSA). This document pointes out the design details of the pool and open water swimming competitions with temperature above 18C. It includes swimsuit including decency, surface covered(shape), composition or other items, colours, material. For male swimsuit should be one piece, limited under navel or below the knee, the style should not offend morality, have good taste and very freely to use colours. There are 9 issues of the materials of swimsuit.

- **Health**: the material needs to keep away from health and risk.
- **Type of material:** Swimsuit can be only textile fabrics.
- **Surface treatment of the textile fabric:** coating, printing, impregnation, heating…should no open mesh structure of the base textile fabric. Following the thickness, permeability and flexibility in production stage. The treatment of seam can be sawn, welded, taped, glued…etc. Sponsor logo is able to print or affixed on the base material or labels.
- **Flexibility**: flexible and soft folding.
- **Regular flat material:** material shall be regular and flat, unable form outstanding shape or structures. Thickness limitation is 0.8mm and the thinnest points of the material no less than 50%.
- **Variation of colours**: Do not affect compliance with tested value limits.
- **Outside application**: No outside application.
- **Variety of materials**: Textile fabrics
- **Combination/ inside layer**: No more than two layers of materials and fabrics. Permeability and thickness of materials need to set for rules. Inside layer of material can be use for comfortable, protection. Outside layer is unable to outstanding, shape or structure.

3 issues of the measured material values

- **Thickness**: The total thickness of materials, which is both layers, is 0.8mm. However, the seam has function. It's width and thickness result does not apply to the thickness limitation.
- **Buoyancy:** The swimsuit shall not have buoyancy effect above 0.5 Newton after application of vacuum.
- **Permeability**: The materials, which except on seams, logos or labels, must have any point a permeability value of more than 80 l/m^2/second. The permeability values are measured with a standard multidirectional stretch of 25%.
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(IV.) MMG Electronic Devices

Professor Sung-Nien Yu in department of Electrical Engineering National Chung Cheng University is a dominated researcher in Mechanomyogram technology about finger motion recognition in Taiwan. Professor Cheng-Tang Pan in department of Mechanical and Electro-Mechanical Engineering National Sun Yat-Sen University and Professor Ing-Shiou Huang in department of Physical Therapy National Cheng Kung University are both devoted themselves in MMG research of application sensors and rehabilitation patients.

In 2016, Industrial Technology Research Institute investigates on device-muscle signal streaming technology and technology transfer to CoolSo Technology Company (Ministry of Economic Affairs,2018). It is able to gain and to analyze parameters data of muscle strength, explosive power, physical activity level and muscle fatigue by Virtual Reality (VR). MMG is a low frequency vibration that observed when a muscle is contracted using suitable measuring techniques (Aoki, Takei, Minh-Dung, Takahata, Matsumoto, Shimoyama, 2016). EMG(Electromyography) technologies assess to muscle activity and the movements like swimming (Hussain, Sundaraj, Low, Lam, Ali, 2018). Hussain, Sundaraj, Low, Kiang, Talib and Nabi (2017) observed that fatigue in brachii muscles of human physiology vai MMG. Suzuki and Uchiyama (2016) study in evaluation of footwear and foot muscle during walking.

Methodology

This study adopts a hands on method, laser cutting technology, invention patent No. I1621405 (Huang,2018) for the 3D sculpturing garment manufacturing method, and computer aid design (CAD), such as CLO 3D and Gerber.

Experimental work

The design procedure is divided into four steps; i.e. design preparation, pattern calculation, garment realization, distribution of a primary sample, and feedback. The smart swimsuit design procedure takes 9 hours, including a 30-minute user interview, 1 hour to completed the design illustration, 1 hour for technical drawing, 4 hours to produce the garment pattern, and 2 hours to construct the garment.

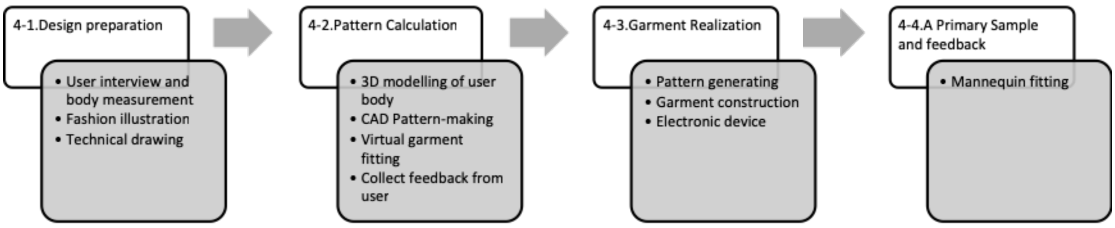

Figure 1. Four steps for the experimental work in this study.

(I.) Design preparation: user interview, fashion illustration and technical drawing

The author interviewing a Taiwanese national swimmer, Mr. Wong, to understand his needs from performance wear. This study illustrates design details on body muscle. The research uses photographic measurement to gain the users' body data.

Figure 2. The author interviewing a Taiwanese national swimmer, Mr. Wong, to understand his needs from performance wear.

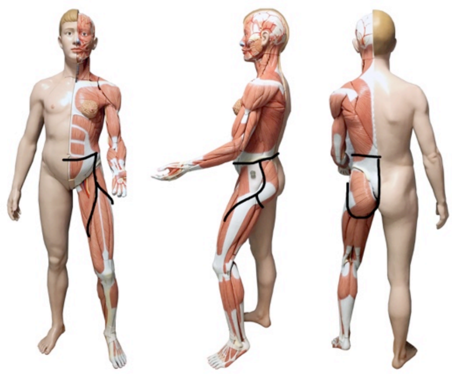

Figure 3 The fashion sketch (see black stork) is followed by body muscle.

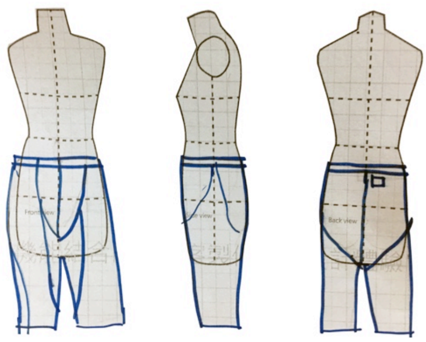

Figure 4 Setting slashes and an electronic device in the scale grid. Each grid represents 5cm X 5cm of the mannequin.

Figure 5 The research uses photographic measurement to gain the users' body data.

Collecting the body parameters from the user, this study adopts both manual and photographic measurement after the interview step. The data set offers the researcher the opportunity to create an adjustable male avatar model in CLO 3D at the next stage with reliability and accuracy.

(I.) Pattern calculation:

3D modelling of the user's body, CAD pattern-making and virtual garment fitting, after first collecting feedback from the user. Based on the technical drawing of the garment, the author illustrates the silhouette, slash, elastic band, silicon band, and cover stitches on the avatar. Then, the swimsuit pattern is executed based on the measurements of the avatar. The research adjusts virtual model in CAD by following both of manual and photography measurement data.

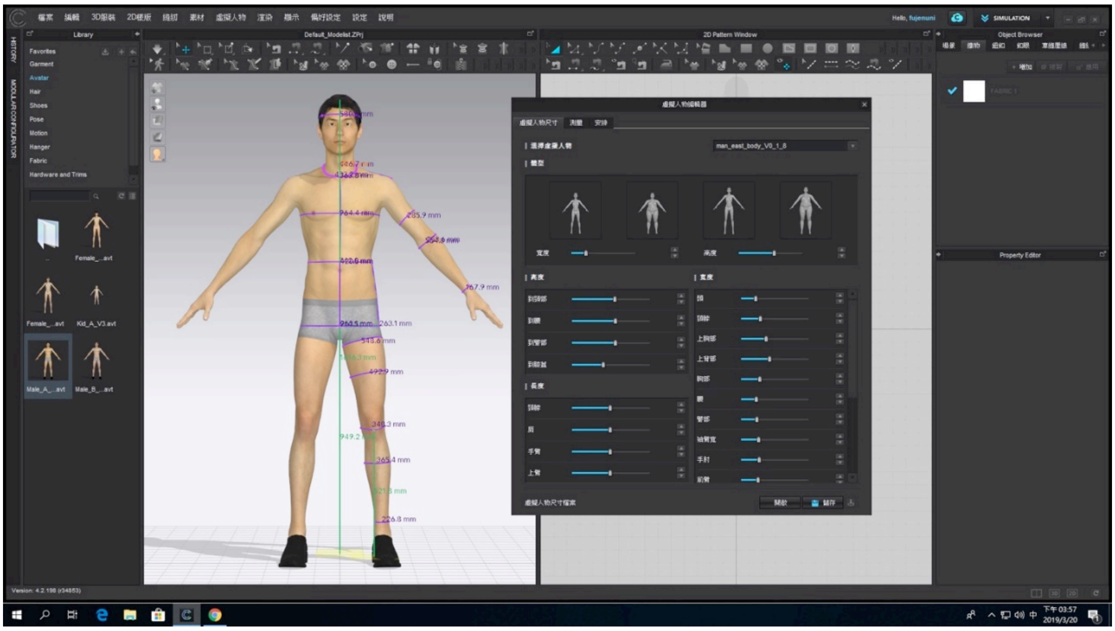

Figure 6. The vertical and horizontal parameters for the avatar in CLO 3D.

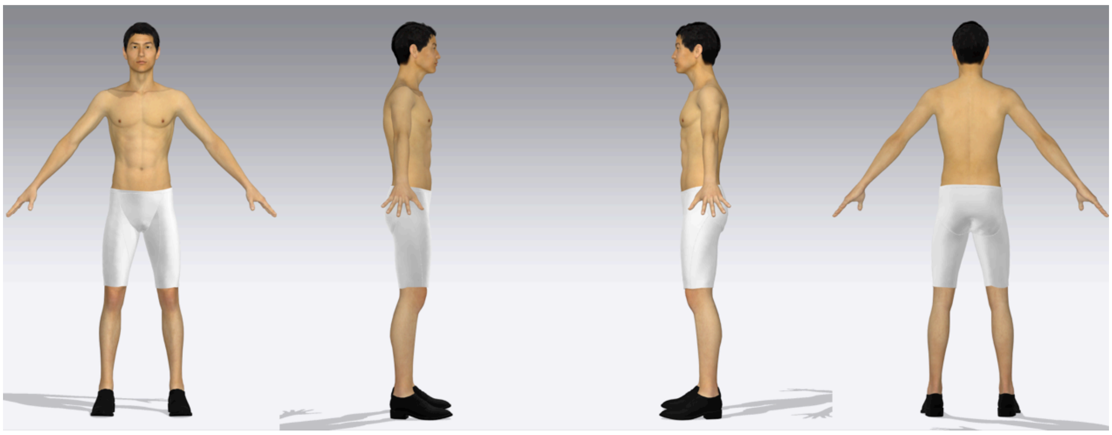

Figure 7. Four views of Stimulation in white using CLO 3D.

The author enters the textile data parameters for stretch, droop, weight and thickness, when simulating the fabric on a virtual model in the CLO 3D system, so as to be able to preview and refine the results of the garment construction before the garment realization step, to reduce the time spent creating the first sample garment. The study produces a virtual catwalk film when previewing the smart swimsuit for the fashion show. This pattern-making method aims to improve on the current method used by the fashion industry, i.e. trial and error. Moreover, the author collected feedback regarding smart swimsuit design from the user to ensure the garment details and pattern met expectations.

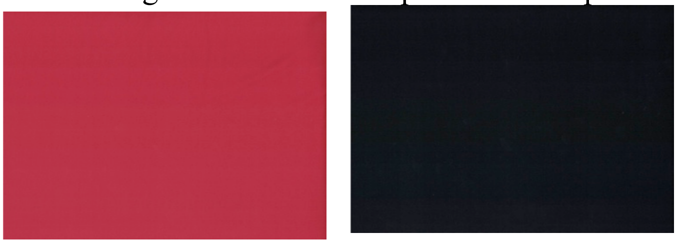

Figure 8. The two professional swimming textiles for the Olympic Games.

Figure 9. A Silicon band is integrated to ensure the swimsuit grips the skin.

After tracing three grains of fabric for testing, the research uses the wheel cutter to cut three test fabrics. Measuring the textile weight, the research found to be 2.8g per 22cm X 3cm piece and to measure fabric thickness as 0.34mm. Entering measuring textile drooping and spread data to CLO 3D system, the research is able to see realtime four views of the simulated design in colour using CLO 3D.

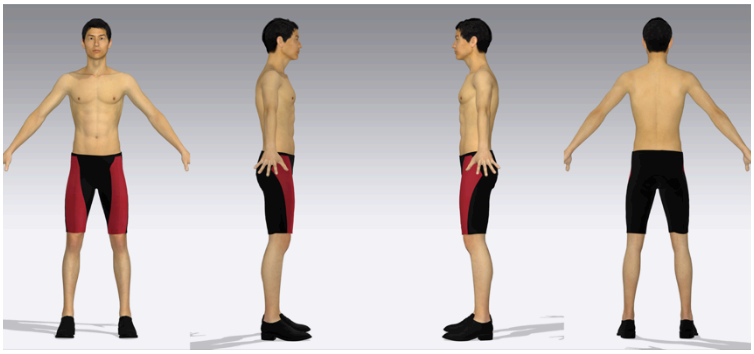

Figure 10. A preview virtual catwalk show helps define and resolve garment problems before the first garment sample is made.

(II.) Garment realization: pattern generating and garment construction with an electronic device

Before generating the garment pattern, the research identifies any problems with the virtual pattern produced in CLO 3D and checks it with the Gerber system. A pattern is printed and cut-off using the printing machine. Professional printer prints and cuts the garment pattern. Laser cutting machine is used with functional fabric to obtain garment pieces for garment construction. Thus, the pattern for the smart swimsuit is intended to create the pattern ready for sewing.

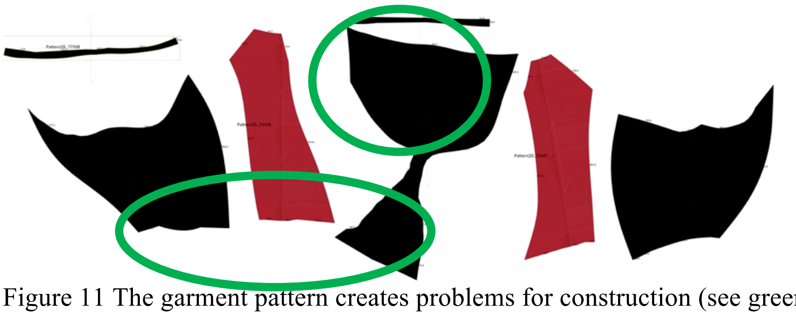

Figure 11 The garment pattern creates problems for construction (see green circles); i.e. the pattern outline is not smooth.

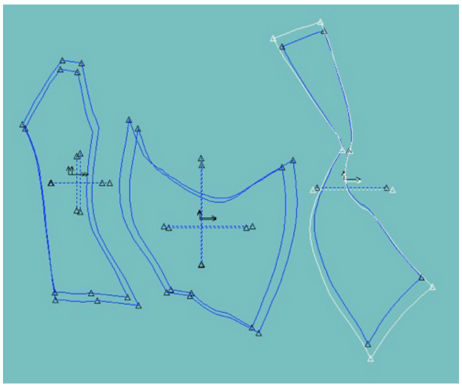

Figure 12. Using 31% Spandex and 69% Nylon knitted functional fabric, this study reduces the pattern data sets by 12% for straight grain and 10% for cross grain.

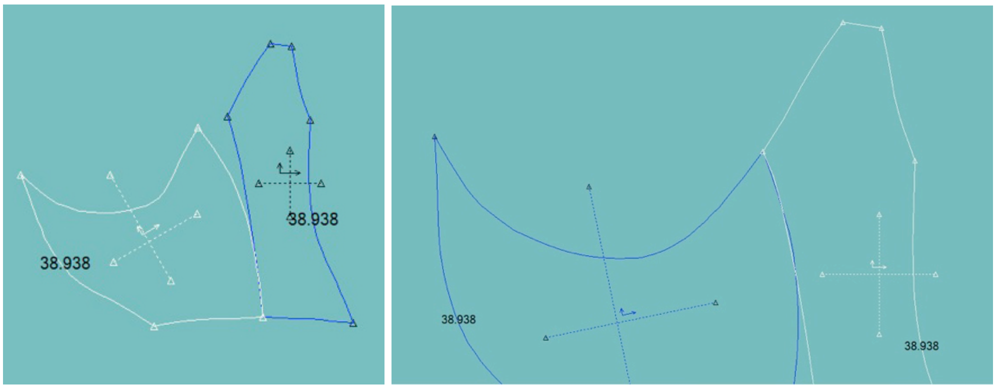

Figure 13 & Figure 14. These two images reveal two ways to proof the garment pattern into a seam.

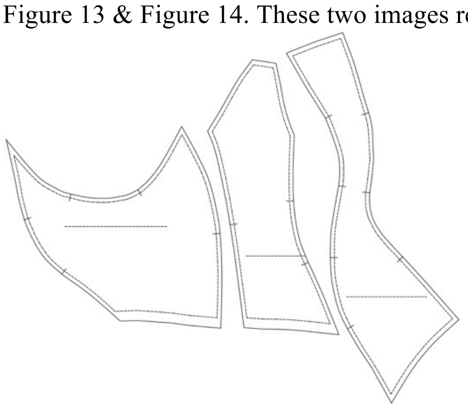

Figure 15. Making the pattern giving a seam allowance.

(III.) A completed first garment sample and feedback: mannequin fitting

The MMG electronic device is located on the right back panel of the garment. The garment details showing the silicon band on the inside layer.

Figure 16. Front, left-side, back and right-side views of the smart swimsuit.

Conclusions

The four research results, are set out below.

- A good ‘design method‘ for smart styled clothing and garment patterning is to adopt technology to reduce the time required to create the primary smart garment sample.
- The professional swimsuit was created in just 9 hours; from design preparation, pattern calculation, garment realization and production of the first smart swimsuit sample. When compared with existing fashion design methods and procedures used in Taiwan, this study offers a high degree of efficacy and accuracy from the design sketch stage to the production of the first sample.
- The pattern for the swimsuit provides a good fit for a male national athletic swimmer.

However, the CLO 3D system establishes an avatar model that is then difficult to adjust for multiple users for several reasons. Firstly because the body of each athlete is unique. Secondly, the CLO 3D makes a design smoothly fitted to the avatar silhouette smooth, and so the avatar’s body parameters vary for different swimmers.

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