The Science and Technology of Clothing Appearance and Fit

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1. Introduction

Decoration, modesty and protection are the three most fundamental motives of wearing clothing (Flugel, 1971). Two of these three primary motives, viz. decoration and modesty, are directly related to clothing appearance (or image) and fit. Today there have been numerous developments of 3D body scanners and considerable researches on mass customization aiming at providing individually fit garments to the diverse consumers (Russell, 1999). The full implementation of mass customization, however, requires bridging the developments in a number of different areas, which include fashion aesthetics, measurement technology, computer aided design, human anthropometrics and sizing.

This paper discusses this important interdisciplinary subject from the scientific and technological perspective. It is intended to highlight the major progresses so far and project future research and developments.

2. Beauty and Its Relation to Fashion

2.1 Beauty and Attractiveness

Clothing is not just worn for utility reasons, but more importantly for beauty. What is beauty? One school of thinking believes that beauty is in the eye of the beholder, that individual attraction is a result of personal experience, cultural background and specific circumstances. Naomi Wolf in her book, The Beauty Myth, argues that there is no such thing as a quality called beauty that "objectively and universally exists" (Etcoff, 1994; Wolf, 1991). Some modern philosophers also believe (Gaut & Lopes, 2001) that there is no principles of beauty, although there is a rational basis for genuine judgements of beauty.

Nevertheless, the assumption that beauty is just an arbitrary personal preference may simply not be true. It cannot explain the fact that even two-month-old infants prefer to gaze at faces that adults find attractive (Langlois et al., 1987).

If there are universal principles of beauty, what are they? Ancient Greeks believed that the world is beautiful because there is a certain measure, proportion, order and harmony between its elements (Gaut & Lopes, 2001). For centuries, Golden Ratio or Golden Proportion, a ratio of 1:1.618 has been considered as perfect ratio for beauty(Fig. 1). It can be seen in nature and use for art and architectural design. Linguists (Pinker, S., 1994) discovered that, although the same sound may mean entirely different in different languages, there is a universal grammar underlying the combination of the sounds. Similarly, it has been suggested by many philosophers that beauty stem from the relationship between the consisting elements of a whole (Humphrey, 1973). Evidenced from the rhyme of music and poem, philosophers in earlier 20th century realized that such beauty is likeness tempered with difference or the fusion of sameness and novelty. Modern psychologists (McClelland et al., 1953) and biologists

Fig 1 Golden section in nature, design and architecture (source. http.//www.goldenmeangauge.co.uk/golden.htm)

have echoed that claim. They found that men and animals, who have been exposed for some time a particular sensory stimulus, prefer new stimuli which are slightly different from the one they are familiar with. "The likeness tempered with difference" is pleasing to the classification process, which is important to biological survival (Humphrey, 1973).

The classical average Greek body proportions have been widely considered as ideal for centuries (Horn & Gurel, 1981), despite of the fact that beauty ideal has never been static. It varied from time to time and from culture to culture. The Greek ideal female figure is shown [Fig. 2] The various body dimensions are measured in the unit of head length. For both the male and female, the height is approximately seven and half heads length, with the fullest part of the hipline at wrist level dividing the total length exactly in half.

Evolutionary psychologists have suggested WHR (waist-hip ratio) and BMI (body mass index) as important visual cues of female physical attractiveness. Recent research by Fan et al.(2004) discovered that a new parameter called VHI (Body volume divided by the square of the height) is the most direct visual determinant of female physical attractiveness. [Fig. 3] plots the strong relationship between VHI and female attractiveness.

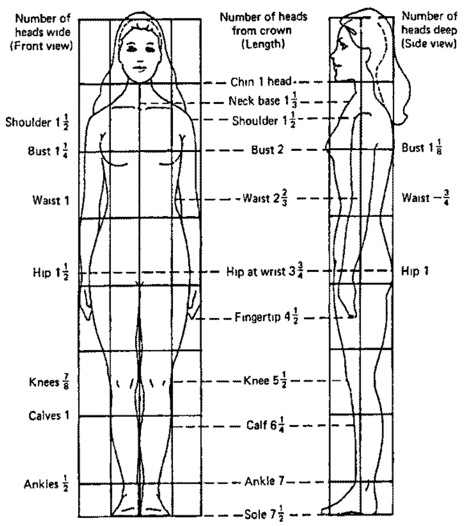

Fig 2 Ideal Greek proportions of female Fig. (source: horn & gurel, 1981)

2.2 Enhancement of Body Image by Clothing

Body image is important as it is strongly related to self-esteem and the development of personality

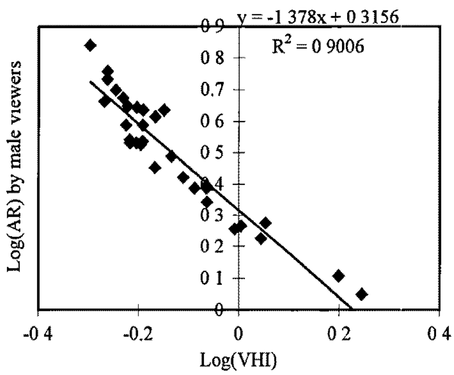

Fig 3 Relationship between AR and VHI. Note: AR: attractiveness rating. (source: Fan *et al.*, 2004)

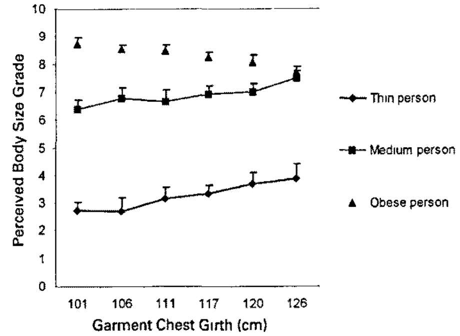

Fig. 4. The perceived body size grade of the thin model, medium model and obese model (source: Fan *et al.*, 2003)

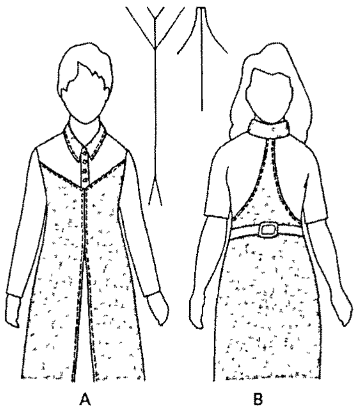

Fig. 5 Effect of design on the perception of body proportion (source: Horn and Gurel, 1981)

attributes. Body image can be enhanced by clothing and the degree of enhancement is strongly related to clothing fit (LaBat and DeLong, 1990).

The effect of clothing fit on body image is different for people having different body builds. For example, it was found (Fan et al., 2003) that, for thin and medium build persons, the perceived body sizes are bigger when wearing T-shirts of larger sizes. However, for an obese person, wearing a large size T-shirt tends to make him look thinner.

With the understanding of the principles of visual perceptions, the creativity of illusion created by dressing is in the hand of consumers and designers. [Fig. 5A] shows a dress, in which the Muller-Lyer principle is applied to create an appearance of increased shoulder width and body height for a shorter figure with a sloping shoulder.

3. Garment Fit, Body Scanning and Sizing

3.1 3D body scanning

To make garments fit and looking good to an individual, it requires a reliable and precise body measurement system. Considerable developments have been made worldwide in recent years and many such systems are now commercially available. These include the 3D body scanning systems from LASS of Loughborough, UK, Tecmath of Germany, [TC]2 of USA, Telmat of France, Cyberware of USA and Cubicam of Hong Kong. [Fig. 6] shows different body scanning systems available.

3.2 Sizing and Grading

With the powerful 3D body scanning technology, the next step forward is to develop appropriate sizing systems and grading rules so as to produce ready-to-wear fashions that fit to intended group of people. Conventional grading method was believed to be flawed in maintaining the proportion of the original design over a range of sizes (Cooklin, 1997). There is also a need for establishing optimum sizing systems (Ashdown, 1998) that would accommodate as large a percentage of a population as possible.

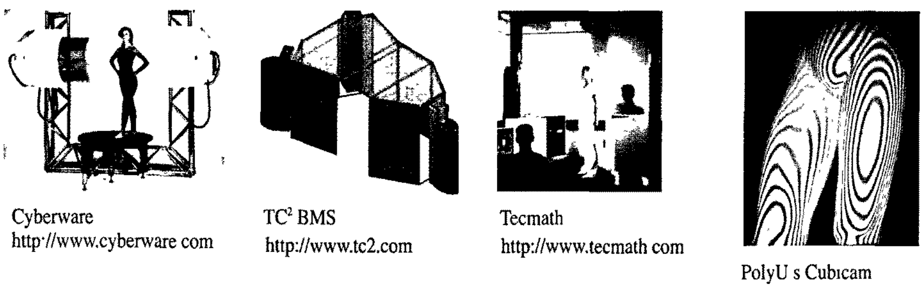

Fig. 6 Some 3D body scanners in the market

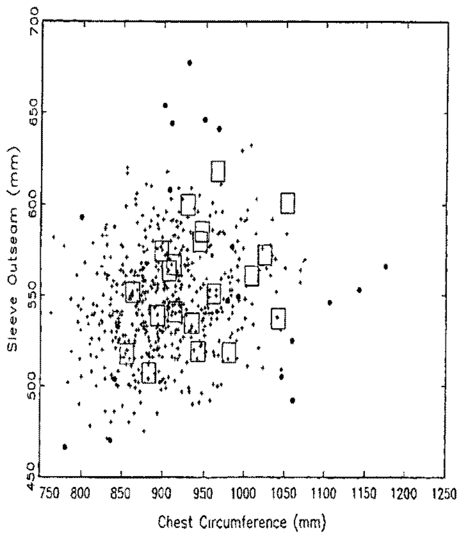

Fig. 7. Optimum sizing system generated by McCulloch *et al* (1998)

Based on multivariate optimization techniques, McCulloch et al. (1998) developed a strategy for establishing optimal sizing systems. [Fig. 7] shows the accommodation of such as optimal sizing system for a population. The accommodation rate of the sizing system is much higher than those of traditional sizing systems, however it presents difficulties for grading. Further work is required to balance the need for simplicity, which is essential for effective grading, and the need for maximum accommodation rate.

3.3 Garment design for individual fit

The ultimate goal is to design garments that fit and appear beautiful on each individual. There has been numerous publications by tailoring experts on how to alter garment patterns for fitting. For example, adding ease to garments worn by large women to camouflage the body shape (Hackler, 1984), alteration of the pattern for narrow, erect or uneven shoulders (Roehr 1993), alteration of trousers patterns according to the shape of the lower body (Shu and Liu, 1997). Researches have therefore been carried out to develop garment patterns from the body anthropometrical measurements. Gazzuolo et al. (1992) developed statistical regression models to predict the dimensions of a planar pattern (i.e. a close-fitting experimental garment pattern) from both traditional and photographic body measurements. Shen and Huck (1993) developed a methodology for developing female bodice pattern from photographic and physical measurements. Researches are currently carried out in Hong kong (Chen, Fan and Yu, 2001) to predict shirt patterns from 3D body measurements, fabric properties and fitting requirements using Artificial Intelligence.

4. Clothing Appearance and Its Relation to Clothing Materials and Manufacture

Another important dimension of clothing appearance is material quality and garment workmanship. In order to achieve desirable clothing appearance, color fastness, fabric wrinkle recovery, pilling propensity, fabric and garment drape, compatibilities of trimmings and shell fabrics as well as seam appearance are important factors to be considered.

Fabric wrinkle recovery is the ability of fabrics to recover from induced wrinkles or to retain a smooth surface appearance after wear and repeated laundering. The method often used in the industry to evaluate the wrinkle recovery of a fabric is AATCC Test method 128 'Wrinkle Recovery of Fabrics: Appearance Method'. The principle of the method is to induce wrinkles in the fabric under standard atmospheric conditions in a standard wrinkling device under a predetermined load for a prescribed period of time. The specimen is then reconditioned and rated for appearance by comparing it with 3-dimensional reference standards (AATCC Wrinkle Recovery Replica).

Pilling is the formation of pills and other related surface changes (e.g. fuzzing) on textile fabrics during garment wear can create an unsightly appearance. This is a particularly serious problem with some synthetic fibres, where the strong synthetic fibres anchor the pills to the fabric surface, not allowing them to fall off as is the case with the weaker natural fibres. The pilling resistance of fabrics is normally tested by simulated wear through tumbling, brushing or rubbing on a laboratory testing machine. The specimens are then visually assessed by comparison with visual standards (either actual fabrics or photographs) to determine the degree of pilling on a

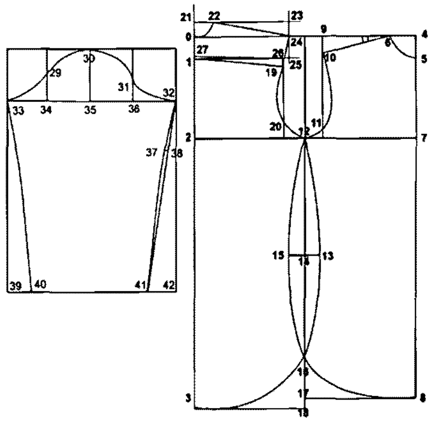

Fig 8 Prediction of shirt pattern (source: Chen et al , 2001)

scale ranging from 5 (no pilling) to 1 (very severe pilling).

Drape is the ability of a fabric to hang limply in graceful folds, e.g. the sinusoidal-type folds of a curtain or skirt [Textile Terms and Definitions of the Textile Institute]. Initially, work on drape concentrated on its accurate measurement and on the empirical prediction of drape from the fabric mechanical properties, notably, bending and shear rigidity and hysteresis. Such an important contribution is due to Cusick, whose drapemeter is still a commercial testing instrument of fabric drape. More recently, however, attention has increasingly focused on modelling garment drape, this being important for developing 3-D garment CAD systems(Fig. 9). Ideal drape models should not only be able to display the static drape of the garment realistically with 3-D renderings of design features, colours and surface textures, but simulate the animated dynamic drape. It should have the capability to convert 3-D shapes into 2-D patterns or vice versa. Although significant improvements in the drape models have occurred over the past two decades, further development in this area is still needed. Although fabric coefficients can be entered into the models, the representation of the fabric drape is still not sufficiently realistic. Seams and garment constructions are not considered properly. When 3-D animation is to be achieved, the challenge is even greater. The resolution of the 3-D virtual garment is still low in real time presentation. Owing to the complexity and high polygon calculation, the computation time to achieve 3-D animation is difficult hurdle to overcome (Fan et al., 2001).

Garment construction and manufacture are also related to the aesthetic quality of clothing. Fusible interlinings and shell fabrics should be compatible in order to avoid rippling of the fused areas and desirable drape. Seam pucker should be avoided during making up in order to achieve smooth surface appearance.

5. Evaluation of Clothing Appearance and Fit

Clothing appearance and fit are aesthetic quality of clothing. Visual assessment is normally carried out in the industry with the aid of photographic standards such as the one shown in [Fig. 10] There is however a trend towards objective evaluation of clothing appearance and fit for reasons of reliability, consistency and accuracy. In terms of garment surface smoothness (i.e. wrinkles or puckers), considerable developmental researches has taken place since 1950s. Early developments were not widely accepted due to problems in terms of accuracy and reproducibility. With the development and wide application of computer and sensory technology, computerized systems were developed in the last two decades. A CCD camera is quick in capturing the visual image, but has difficulty in differentiating the wrinkle or pucker profiles from the colour pattern. Laser triangulation techniques are considered to be more accurate and reliable as it obtains the geometrical profiles of the fabric or garment surface, from which the degree of the smoothness of clothing sur-

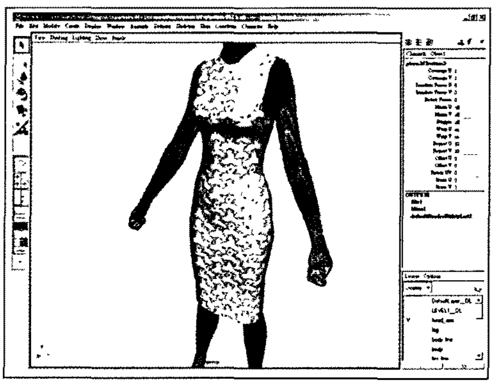

Fig. 9. Garment drape model in maya cloth™

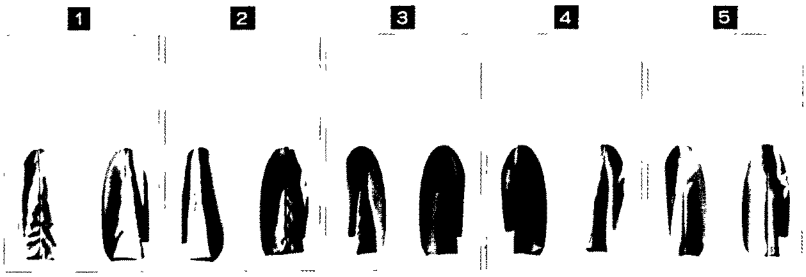

Fig. 10. Photographic standards of tailored garments

face can be determined quantitatively (Fan et al., 1999; Fan and Liu, 2000). Laser systems are very successful for evaluating the surface smoothness (e.g. wrinkle or pilling) of fabrics or a single seam, however further improvements are necessary for them to be used for evaluating the whole garment due to the cost of the system and computation time. Fig. 11 shows a 3D laser system for evaluation clothing surface appearance.

With regard to the evaluation of garment fit, subjective wearer trials are normally conducted, in which the wearers may be required to perform a predetermined exercise, then rate the fitting in a numerical scale. Attempts are made to develop objective measurements of garment fit. Kohn and Ashdown (1998) developed such a technique by analyzing the video-captured images of slashed garments. Yu et al. (1998) proposed the use of moiré topography to objectively evaluate garment fit. Both Kohn and Ashdown's technique and Yu et al.'s method may not be not suitable for garments with colour patterns. Further work in this respect is necessary.

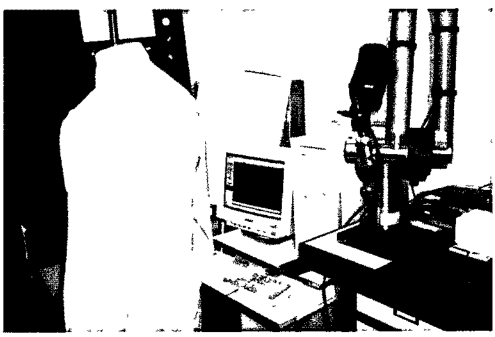

Fig. 11. Garment appearance evaluation system

6. Conclusions

No doubt there have been considerable developments in the field of clothing appearance and fit, particularly in terms of the understanding of the relationship between beauty and clothing design, the development of 3D body scanner and objective measurement of fabric and seam appearance. The future is to integrate the various developments and apply them for fashion innovation.

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