THE HONG KONG POLYTECHNIC UNIVERSITY

INSTITUTE OF TEXTILES AND CLOTHING

PREDICTION OF MEN'S DRESS SHIRT PATTERN FROM 3D BODY MEASUREMENTS

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A thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in this text.

_________________________ (Signed)

CHAN AH PUN (Name of Student)

To my family

and

My son Wang Lik

for their never-ending love,

support and understanding.

Abstract

Nowadays, there are a number of developments of advanced three-dimensional body scanners in the world, all aiming at achieving better fit for diverse consumers. However, a good fit for individual consumers cannot be achieved without establishing the accurate relationship between the fit design and the body anthropometrical data. Traditional methods of pattern drafting are based on basic blocks with relevant formulae and tailor's experience. These methods of pattern drafting have not been validated experimentally and the patterns from these methods may only fit a limited group of people. In order to automate and improve the accuracy of the pattern drafting process, geometrical models have in the past developed and built in the CAD system to convert three-dimensional body measurements into the two-dimensional pattern. Such work was very successful for close-fitting apparel, but may have inherent difficulties for loose-fitting garments, which involve the complex draping of the fabric.

In this study, 59 male subjects, representing the Chinese male population in Hong Kong were invited to take part in this experiment. After comparing the shirt pattern parameters calculated from the traditional drafting formulae with the actual measurements of the fitting shirts made by the tailor, considerable differences were found. One possible reason for the inadequacy of these formulae is that, each pattern parameter may relate with multiple body measurements. To address the above problem, multiple linear regression (MLR) analysis was applied to identify the important body parameters for each pattern parameter and establish the underlying relationship between body measurements and pattern parameters. Although, the results showed that the prediction of shirt pattern based on the MLR model has much improved accuracy compared with the traditional pattern drafting formulae, the prediction is still not accurate due to the possibly non-linear relationships between the pattern parameters and body measurements. Therefore, Artificial Neural Network (ANN) has been applied to establish shirt pattern prediction model from 3D body measurements. ANN has also been applied to establish a model for the prediction of the fitting perception of men's shirts from 3D body measurements and pattern parameter, which can be used by the pattern designers to evaluate the pattern in terms of fitting to the target customer before an actual garment sample needs to be produced. Furthermore, an Artificial Neural Network model was also established to predict the pattern parameters of men's dress shirts from both the 3D body measurements and fitting requirements. The validity and accuracy ANN models established in this study was further evaluated. It was found that ANN model is not only improving the accuracy of pattern prediction, but it is also providing good fit to the wearers.

The study improved our understanding of the interrelationship between the 3D body measurements, fit perceptions and pattern design. The developed models can be coded into a computer program for automatic pattern generation, which is much desired for the implementation of mass customization. Although the present study is limited to men's dress shirts, the original methodology can be applied to the other types of garments in future studies.

List of Publications

Referred Journals

1. A.P.Chan, J. Fan, and W.Yu, Men's Shirt Pattern Design Part I: An Experimental Evaluation of Shirt Pattern Drafting Methods, Sen'I Gakkaishi, 2003, Vol. 59, No. 8, p319-327

2. A.P.Chan, J. Fan, and W.Yu, Men's Shirt Pattern Design Part II: Prediction of Pattern Parameters from 3D Body Measurements, Sen'I Gakkaishi, 2003, Vol. 59, No. 8., p328-333

3. A.P.Chan, J. Fan, and W.Yu, Prediction of Men's Shirt Pattern Based on 3D Body Measurements, International Journal of Clothing and Science Technology, 2005, Vol.17, No.2, p100-108

4. A.P.Chan, J. Fan, and W.Yu, Prediction of Subjective Fitting Perception from Shirt Pattern Parameters and Body Measurements, Submitted to the Journal of Applied Ergonomics.

5. A.P.Chan, J. Fan, and W.Yu, Prediction of Shirt Patterns from Fitting Requirements and 3D Body Measurements, Submitted to the Journal of Neural Networks.

6. A.P.Chan, J. Fan, and W.Yu, Evaluation of Shirt Patterns Designed Using Developed ANN Model, Submitted to the Journal of Neural Networks.

Conference Papers

1. A.P.Chan, J. Fan, and W.Yu, Prediction of Men's Shirt Pattern Based on 3D Body Measurements, World Textile Conference, 4th AUTEX Conference, ENSAIT Roubaix. France, June 2004

2. A.P.Chan, J. Fan, and W.Yu, Garment Pattern Design Based on Human Body's Anthropometric Data, The Textile Institute 82nd World Conference, Cairo, Egypt, March 2002

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Introduction

1.1 Background and Scope of Study

Nowadays, there are a number of developments of advanced three-dimensional body scanners in the world, all aiming at achieving better fit for diverse consumers. However, a good fit for individual consumers cannot be achieved without establishing the accurate relationship between the fit design and the body anthropometrical data. Traditional methods of pattern drafting are based on basic blocks and tailor's experience. These methods of pattern drafting have not been validated experimentally and the patterns from these methods may only fit a limited group of people. In order to automate and improve the accuracy of the pattern drafting process, geometrical models have in the past developed to convert three-dimensional body measurements into the two-dimensional patterns. Such work was very useful for close-fitting apparel, but have inherent difficulties for loose-fitting garments, which involve the complex draping of the fabric. The present study aims at establishing the quantitative relationship between the pattern parameters and 3D body measurements so that garment patterns fit to a specific individual can be drafted based on the wearer's 3D body measurements. Owing to the limited resources and time, this study is confined to the men's dress shirt.

1.2 Objectives

The specific objectives of the study are as follows:

1) to establish a quantitative relationship between 2D pattern, fitting perception and 3D body dimensions;

2) to experimentally evaluate traditional methods and formulae for shirt pattern drafting;

3) to develop a technique and procedure for the assessment of the perception of shirt fitting;

4) to improve the understanding of the relationship between the fitting perception, body dimensions and 2D pattern;

5) to establish algorithm for deriving 2D shirt patterns from the 3D body measurements using multiple linear regression and Artificial Neural Network;

1.3. Basic Idea

The basic idea of the project is to predict the basic shirt pattern from the fitting requirements and human body's anthropometrical measurements, so that patterns can be designed to meet the required appearance and fit for each individual. In mathematical terms, we would like to find the following function:

$$G = f\ (P, B) \qquad (1.1)$$

where, G is a vector of garment pattern parameters; P is a vector of percepts about fitting; B is a vector of body measurements.

The fundamental methodology of this work is to establish Equation (1.1) empirically through applying multiple regression analysis and artificial neural network. To do so, the vectors P , G , B should be determined for different garments and different individuals.

Theoretically, pattern design is also related to fabric properties. Patterns should be adjusted for different fabrics. Due to the limitation in project time and resources, this study is confined to a typical dress shirt fabric. The basic shirt pattern derived from this study can be adjusted for different fabrics in application.

1.4 Research Methodology

In order to achieve the objectives of this project, the following research methodology will be applied:

1.4.1 Literature Review and Interview with Experienced Practitioners

This was the first step for understanding the previous work on shirt fitting, fit evaluation and remaining issues on men's shirt. This is very important for clearly defining the objectives of this study.

For this part of work, journal papers, books and internet publications are searched and studied. Brief interviews with the pattern technicians and designers were held. All were essential for seeking the information on shirt pattern drafting, the problems existed in the market and the previous research in this area.

1.4.2 Human Subjects and 3D Body Scanning

1.4.2.1 Male Human Subjects

In order to evaluate the men shirt fitting and obtain the body measurement data, a number of male subjects in various body sizes were invited as human subjects for the study.

According to the scope of the project, the subjects of this project are male who will wear men's shirt for work. Therefore, the age of the subjects is not important for subject selection criteria. The main criterion is to have subjects with large variations in the body dimensions. According to the tailors, pattern technicians, manufacturers and designers, the sizing system in men's shirt is represented by the neck size and chest size for ready-to-wear market. Based on the above consideration, the subjects with different neck size and chest size as well as body sizes were selected.

1.4.2.2 3D Body Scanning

A three-dimensional body scanner is used to obtain precise anthropometric data, instead of using direct linear measurements on the subjects. The existing body scanner system (Techmath Laser Body Scanner) was used for obtaining the 3D body measurements.

1.4.3 Shirt Samples and Pattern Measurements

1.4.3.1 Shirt Samples

A lot of shirt samples with varying degree of fitting to the male human subjects will be needed in this study. However, in the first phase of the study, only the best fit shirts for the subjects were made. An experienced tailor was contracted to design and make dress shirts for the male subjects. The tailor uses his experiences and intuitions so as to make the best fit shirt for each of the male subjects. The shirts were tried on the subjects to examine the fitting. If the fitting was not good enough, the tailor would modify the garment, or re-make the shirt with a new pattern until a good fit is achieved for the target subject.

1.4.3.2 Men's Shirt Pattern

The shirt patterns are traced back from the fitting shirt. The patterns include front piece, back piece, yoke and sleeve. The patterns were measured by a set of 33 parameters. These include the length between each intersection point and the angle at the shoulder line. These 33 parameters were considered as the necessary and sufficient parameters for the computer to plot the pattern. In measuring the pattern parameters, the average of 5 manual measurements was taken.

1.4.4 Visual Assessment of Fitting Perception

1.4.4.1 Interviews with Experts

The fitting criteria of dress shirts fitting and fitting procedures were established based advice from designers, tailors and pattern technicians.

1.4.4.2 Fitting Assessment

The evaluation form for rating was the shirt fitting designed based on the comments from the experts. There are totally twelve questions for rating different aspects of fitting including tightness or looseness, ease of body movement and appearance in different parts of the body. Ratings are performed after the wearer conducts a series of activities including uplifting and bending forward their hands. Both the wearer himself and the shirt experts were asked to rate fitting.

1.4.5 Data Analysis

SPSS and expert system were used to analyze the experimental data.

1.4.5.1 Multiple Linear Regression

The Stepwise Variable Selection Method of the Multiple Linear Regression is used to select the important independent variables for pattern prediction and to build the relationship between 3D body measurements and pattern parameters.

1.4.5.2 Artificial Neural Network

Artificial neural network (ANN) is also used for the establishment of the prediction models in this project. Past research has found that ANN is especially effective for modeling nonlinear functions or relationships (Fausett 1994, Fan and Hunter 1998, Fan et al 2001). The principle of ANN is to train the model (i.e. adjusting the weights between the nodes in each layer) using experimental datasets so that the output from the ANN is equal or as close as possible to the target pattern. For the application of Equation (1), G are the output parameters, P and B are input parameters.

1.5 Significance of the Study

1) Existing shirt pattern drafting formulae were established based on tailoring experts' past experience. These formulae were there for a period of time and therefore may be out of date. They may also only appropriate for a group of people (e.g. westerners). The validity of the existing formulae for the pattern design of men's shirts will for the first time be evaluated.

2) Identification of necessary and sufficient body measurements for pattern design. Today 3D body scanning systems can provide numerous number of body measurements. However, it is not clear which of these measurements are necessary and sufficient for the pattern design. This study will improve our understanding on what to measure and how to measure the human body for pattern design.

3) This study provides a method for predicting the basic blocks of men's shirt pattern of different individuals.

4) Essential to apparel mass customization, the quantitative knowledge and principles of drafting the basic pattern blocks for individual fit and appearance will be very useful to the designers and essential to the implementation of the much desired mass customization.

1.6. Originality of This Project

Base on the above discussion, this project have the following originality:

1) The methodology of pattern prediction is original and can be applied to the study of the patterns of other garments.

2) The relationship between the body measurements, garment pattern and fitting perception will be quantitatively investigated for the first time and better understood.

3) The traditional pattern drafting method and formulae for men's shirt will be verified for the first time.

4) The important body measurements for pattern drafting of shirt patterns will be identified for the first time.

1.7 Flow of the Thesis

This thesis is separated into ten chapters. Chapter 1 and Chapter 2 are the introduction and literature review. Chapter 3 is experimental and results. Chapter 4 is comparison and evaluation of tailoring experts' formulae for shirt pattern drafting. Chapter 5 is prediction of men's shirt pattern by multiple linear regression. Chapter 6 is prediction of men's shirt pattern from 3D body measurements using artificial neural network. Chapter 7 is prediction of subjective fitting perception from shirt pattern parameters and body measurements. Chapter 8 is prediction of shirt patterns from fitting requirements and 3D body measurements. Chapter 9 is evaluation of shirt patterns designed using developed ANN model. Chapter 10 is general conclusions and recommendations

Chapter 2

Literature Review

Chapter 2

Literature Review

2.1 Introduction

This study is concerned with drafting garment patterns based on body measurements to fit individual wearers for the purpose of mass customization. Pattern design for garment fitting is interdisciplinary related to garment sizing systems, body measurement technology, pattern design techniques and fabric properties. The literature review is therefore intended to cover the contributions in the different related fields. In this Chapter, the literatures are grouped and reviewed in the following categories:

Mass customization (*section 2.2*)

3D body scanner (*section 2.3*)

Anthropometric survey and garment sizing (*Section 2.4*)

CAD technology (*section 2.5*)

Pattern design (*section 2.6*)

Garment fit (*section 2.7*)

2.2 Mass Customization

Mass customization is a concept of combining the advanced technology with the accurate pattern design so as to provide individual fit for diverse customers. It is a new manufacturing trend in which mass-market products (e.g. apparel) are quickly modified one at a time based on a customers' needs (Xu et al 2002). It provides consumers with personalized products manufactured from standard product components (Tail 2001). The idea of mass customization has been discussed for many years. Many researchers believe that it is a global trend for the apparel industry.

One reason for the increasing need for mass customization is the ever-changing requirements of consumer needs in the entire apparel industry (Anderson et al 1997). Mass customization has advantages in better understanding customer demands and shortening product development and product life cycles compared with those of mass production (Fralix 2001). Companies become more competitive as a result of maximizing customers' satisfaction and minimizing inventory costs" (Xu et al 2002).

Mass customization cannot be realized without the relevant technologies. Automatic and accurate body measurement system is essential for apparel mass customization. The recent developments of 3D body scanners created a revolution in mass customization Hye (1999) and Chapman (2000). Automated and accurate pattern design system for generating patterns from 3D body scanning data and fabric properties is also critical for mass customization (Xu et al 2002). CAD technology, incorporating digital virtual human model, virtual try-on, and virtual catwalk, is also necessary as this would offer possibilities of modifying the design before the actual product is made, thereby maximizing customer satisfaction and minimizing inventory costs. The garment manufacturing systems should also be flexible depending on customer specifications so as to produce individualized products (Anderson et al 1995). Weldon (1995) and Buirski (1999) further pointed out that advanced information technology, automation, CAD system and flexible manufacturing are all important for facilitating the implementation of mass customization.

One recent example of mass customization was from Techmath Co. Ltd. The customer can have choices of different high quality fabrics and accessories. The scanned data of target customers and the choices of materials can then be sent through data transfer to one of four manufacturers in Germany. Four weeks later, the customer can pick up the tailor-made clothing at the store. A top German mail order company, Otto Versand, has also started to offer customized shoes via the Internet. Basically, the customer is the designer, and with just a few clicks, shoes can be created in different designs and in five possible colours and the finished products can then be delivered in two weeks (Staab 2002).

Despite of the much progress in the implementation of mass customization, many challenges still lies ahead. Tail (1998) pointed out that body measurements from body scanners were not sufficient for made-to-measure apparel. Many of the necessary measurements involve apparel measurements, not just body measurements. There are also personal choices regarding customer comfort, psychological and aesthetic preference. Fitting requirements, for example, is one of the important elements for implementing mass customization.

Secondly, the existing practice and mind set should also be changed. Most pattern makers in the industry do not know how to alter the garments pattern to fit individual customer, because they have always produced garments to fit their company's sizing system. And there is little practical guidelines in the current literature about the alteration of existing garments pattern in conjunction with current technology. In this regard, Istook (2002) introduced a step by step guideline for using the existing CAD technology to enhance the custom fit of garments.

Thirdly, only a few body scanning systems are available in apparel industry because of the high prices of such systems and they are not well intergraded with the apparel CAD system. 3D garment design technology, which can consider customer's individual's size, shape and requirements, should further developed (Xu et al 2002).

2.3 3D Body Scanning Systems

The first element for the implementation of mass customization is the accurate body measurements by 3D body scanners. Istook and Hwang (2001) pointed out that a comprehensive and accurate set of measurements could help to customize garments for fit. The development of three dimensional body scanning technologies is key to the apparel industry in terms of mass customization.

2.3.1 Principles of 3D Body Scanners

According to Istook et al (2001), Blais (2004) and Fan et al (2004), the principle of three-dimensional body scanners is to capture the outside surface of human body without physical contact with the body using optical techniques or light sensitive devices. The subjects were usually required to wear form-fitting briefs or running shorts during the scanning process. Body scanning systems consist of one or more light sources, one or more vision or capturing devices, software, computer systems and monitor screens in order to visualize the data capture process. The primary types of body scanning systems are light and laser. Leading systems can be found in Japan, the United Kingdom, Germany, France and the United States.

2.3.2 Light-based Scanning Systems

A shadow scanning method developed by Loughborough University was used in one of earliest 3D body scanning systems, which was named The Loughborough Anthropometric Shadow Scanner (LASS) in the UK in 1987.

SYMCAD is Telmat's 3D body scanner and developed in France in 1995 (Russell 2000). The measurement data from Telmat body scanner can be integrated into apparel CAD systems such as Gerber Technology's Accumark system or Lectra System's Modaris software. It takes less than 15 seconds for scanning and generates 70 body measurements. MySize's body scanning system (Champman 2000) and Eastman's Telmat body scanning device (DesMarteau 1999) are also the scanning products from Telmat.

The Textile Clothing Technology Corporation (TC2) in the United Stated developed the products 2T4 (Fralix 2001) and 3T6 (Mckinnon 2001). It uses a phase measuring profilometry (PMP) technique, which is similar to moiré light projection techniques. According to Istook et al (2001), "it uses a white light source to project a contour pattern on the surface of an object. A couple charged device (CCD) camera linked to a computer detects the resulting deformed light strip. The superimposed projection grating lines interact with a reference grating, forming the fringes. As irregularities in the shape of the target object distort the projected grating, fringe pattern result."

Another white light system with a variation of moiré fringe for capturing the 3D shape of an object is Triform, which is developed by Wicks and Wilson Limited in the United Kingdom.

Moiré topography is one of the light-based scanning systems. Many researchers used this technique to evaluate the body shape and fabric properties on shaping etc. This method can capture a three-dimensional image onto two-dimensional fringe pattern (Yu et al 1998). Tanaka et al (1982) used moiré topography to investigate the partial shape of the human body such as breast, anterior chest slope, bugle around the scapula and back slope in order to get a fundamental data of clothing well fitted to the human body. Suda et al (1983) used this method to evaluate the draped shape of various kinds of fabric. Matsuoka et al (1984) also used this method to evaluate the three- dimensional shape of wrinkled fabric and applied on bagging. Tomita et al (1987) based on the technology of moiré topography for obtaining several torso replicas of aged women in order to enhance the fit of the traditional drawing method of the flat pattern. The mobility of the pants was evaluated by its amounts of the ease at the hip and the thigh by Tomita (1989). Yu et al (1995) developed a moiré system for the measurement of brassiere cups. The unstable soft material method for measuring both convex and concave surface profiles of a three-dimensional form was evaluated by Yu et al (1997).

One of the moiré topography scanning systems named Cubicam was developed by The Hong Kong Polytechnic University in 1999.

Another light-based system is infrared, which has been applied in Japan to develop the Hamamatsu Body Lines (BL) scanning system since 1980s. It uses near infrared LED (light emitting diodes) to obtain the scan data. Near infrared light is reflected from the subject being scanned and is collected by the detector lens.

2.3.3 Laser-based Systems

Cyberware Limited, in the United States, has developed the body scanner since 1987. In 1995, Cyberware developed a 3D body scanner with WB4, WBX, ARN Scan, Fast Scan and Vitus Systems. The scanner projects a line, which is reflected into cameras located in each of the scan heads.

The Techmath scanner developed by a German Company in 1995 (Tail 2000) employs the laser scanning principle. The company is a leading scanner supplier in the industry. Techmath 3D body scanner takes only 1.3 seconds to scan an object and the total scanning time is within 10 seconds.

Voxelan is developed by NKK in Japan and later taken over by Hamano Engineering Co. in 1990. It is optical 3D scanning system that scans the body with laser.

Bunka women's University also developed a 3D body scanning system through joint industry-university research project with in Japan in 2001. It uses halogen light and takes about one second to obtain the body measurements, with accuracy 1 to 3mm.

2.4 Anthropometric Survey and Garment Sizing

The improper garment sizing in the market is a prevailing problem. That means the proportion of the garments and the existing grading methods are not fit to the various groups of customers. This problem may be due to the out-dated anthropometric data and the lack of sizes appropriate for the full range of variation in body type that exists in the population (Asdown 1998). The existing grading rule in the market is another concern (Cooklin 1997), as the existing rule for grading the various sizes of a garment style is based on pervious experience and outdated anthropometric data. Those rules have not been validated experimentally. The one of possible solutions for providing an appropriate sizing of garment and grading rules for producing a range of ready-to-wear apparel is the anthropometric survey using 3D body scanner.

Anthropometric survey is a consequence of the development of ready-to-wear clothing industry. In 1910, the apparel industry started using size designations to produce and sell ready-to-wear clothing (Xu 2002). Researchers conducted many anthropometrical surveys in these ten decades aim at providing updated body size information to enhance the accuracy of garment fitting.

Many anthropometrical surveys have been done on different group of people, such as women, men, people over 50 years old and pregnant women etc. Gordon (1986) revealed the problem of the size fitting of the female uniform for U.S. Army. He then derived mathematically from the U.S. Army's anthropometrical database an integrated sizing system for men and women. Workman (1991) investigated the body measurements in sizing variation. He especially focused on comparing current standards for size 8 and 10 with those of the past decade. Kee (1994) conducted the anthropometrical survey of Chinese women in Hong Kong and China for developing the sizing system by comparing the size difference of block patterns between the Hong Kong women and Mainland Chinese women.

Manley (1997) conducted an anthropometrical measurement study for the pregnant women's protective wear. Some researchers applied the anthropometrical survey for garment design and fit assessment. For instance, Momota et al (1998) applied the principle analysis to understand physical type characteristics of the upper half body of adult males. Iwasaki et al (1998) stated that physique and body forms are very important in garment design, therefore, researchers based on necessary information from anthropometrical survey on each age group of 50-70 years old women for improving the clothing design. Fberle et al (1999) conducted a simple survey for comparing the difference between chest girth and waist girth in different age groups of western adult male. All of them concentrated at the relationship between the body dimensions and the garment design.

Recently, Asdown (1998) reiterated the importance of using the anthropometrical database in terms of various body dimensions to create optimized sizing so as to improve garment fit to the population. Xu et al (2002) reported that many survey showed the anthropometrical data for clothing design was outdated and cannot provide perfect fit to the current population. One of the reasons is due to the outdated anthropometrical data.

Anthropometrical data should be updated through periodic surveys in different parts of the world, which is time consuming and expensive. The development of 3D body scanners provided an effective and efficient tool for collecting accurate body measurements.

With the availability of 3D body scanners, anthropometric survey was conducted in different parts of the world. Comparatively, there are more anthropometric surveys on the western population (Winks 1998), whereas there is only very limited anthropometrical survey on oriental population so far, With regard to Hong Kong, there is so far no updated anthroprometric data (Kee 1994). Recently, a project was conducted by The Hong Kong University of Science and Technology to carry out an anthropometric survey of Chinese people in Hong Kong by using the three-dimensional body scanner. However, no results are published.

2.5 CAD Technology and Computer Simulation on 3D Virtual Garments

Apparel CAD is a very important element in mass customization. CAD is a well-known tool in the clothing industry. CAD systems are widely used in clothing industries, such as textile design, grading systems, marker making systems, pattern design software, pattern generation software etc. The following review is focused on CAD for garment design.

2.5.1 Researches on CAD Systems

Many researchers contributed a lot to this area. Imaoka et al. (1989) developed a three-dimensional apparel CAD system for drape simulation and sample making. The basic idea of the system was to create natural shapes of the garments by considering the four main factors, viz. the mechanical properties of fabric materials, geometrical and topological shapes of paper patterns, shape of the human body and the way of dressing.

Yamakawa (1989) developed the computer patternmaking system, which makes garment patterns automatically by the input of the fashion drawing, as there were no systems for patternmaking. Authors regulated the rules for drawing fashion design. Then they calculated the measurements of the fashion drawing and the measurements of the real garments. The ratio of those two measurements were defined and used for tight fitting dress pattern design. The wearing comfort on fitting perception was not verified before establishing this computation system.

Heisey et al (1990) developed algorithm for draping a basic skirt in three-dimensional form and convert the individually fitted skirt to two-dimensional pattern. These researchers claimed that the factors related to garment fit were the physical characteristics of factors from which the garment would be sewn, the figuration of the body and the cultural definition of the garments.

Kang et al (2000) developed an apparel CAD system to perform automatic garment pattern drafting and the prediction of the final shape of designed garment dressed on the human body. They based on the traditional pattern drafting methods and grading rules to create the computerized pattern design script language. The cross-sectional value from the anthropometrical data was used as the standard for the size accommodation to make a resizable human body. The designed garment pieces were divided into fine quadrilateral elements using a specially coded mesh-generating program for draping the garment. The contact condition with human body, deformations, and the weights of the elements constituting the garment pieces, as well as the surface texture of the cloth were also considered.

Carrere et al (2000) stated that "body scan data does not automatically integrate with any commercially available CAD/CAM system or measurement extraction algorithm process". Recognizing this problem, their research aimed at developing exchange protocols for the current body scanning devices, CAD systems and creating the conceptual model for body scan/CAD data exchange and garment development.

Istook (2002) proposed a step by step guideline for using the CAD technology so as to enhance the custom fit of the designed garments. This addressed the problem that most pattern makers in the industry do not know how to alter the garments patterns through CAD to fit individual customer, as they have always produced garments to fit their company's sizing system.

The recent advancement in apparel CAD technology includes the 3D virtual garment simulation. The development of garment visualization on 3D computer environments assists the designers in assessing the design, fabric suitability and the accuracy of developed patterns. This concept of 3D CAD system provides a true representation of garment from the computer platform and views the virtual garment from any angle. In such systems, flattening algorithms are also applied to convert 3D image to 2D patterns. Furthermore, a virtual dressing facility, where conventionally-designed pattern shapes are assembled into a garment and viewed on a 3D body form. It plays an important role in made-to-measure and customized garments (Hardaker 1998). Designers can also collaborate with buyers by enabling them to play with fabric and style options. Texture mapping garments can then be posted to WEB-STORE, a 3D virtual shop environment that enables users to walk-through in real time over the web (Chapman 2001).

The incorporation of body measurement software and pattern generation software could offer improved custom fitting (Kathiervelu 2001). CAD for garment design has been very successful for close fitting garments, however for loose-fitting garments, challenges still remain as it involves complex draping modeling.

2.5.2 Commercial CAD Systems

There are a number of commercial apparel CAD software available from different companies. For instance, AccuMark™ from Gerber technology. AccuMark APDS-3D is a product from Asahi Chemical Industry Co. Ltd., which is a virtual draping program, allows pattern makers to select patterns from AccuMark™ Pattern Design and instantly view them assembled on a 3D dress form.

Lectra system provides two versions of software, which are LectraCatalog and LectraOnline. LectraCatalog combines an Oracle-based database with texture mapping on a 2D or 3D image, where styles, fabrics and trims can be mixed and matched instantly and displayed photo-realistically. It can be used for face-to-face design or as a Web-enabled catalogue. LectraOnline is an e-prototyping service that provides virtual sampling for apparel customers by combining texture mapping with 3D garment construction. It automatically generates lightweight files from pattern pieces created in two dimensions, from a fabric photo or scan, or from a virtual fabric. The designer submits a file over the Internet along with a photo of the fabric, and LectraOnline sends back a three-dimensional virtual garment.

There are two types of 3D CAD software provided from PAD system (Shepard 2000). They are 3D Virtual Design and Haute Couture 3D. 3D virtual gives the possibility to visualize all modifications to pattern pieces in real time. The 3D image is automatically generated from the two dimensional pattern. Haute Couture 3D is an application which addresses the growing needs of the 3D animation industry with regards to the production of high quality, photo-realistic, 3D-garments. This software also includes a graded, framed and sewn pattern library.

Maya Cloth™ is a spring based dynamics systems that adds new simulation possibilities to Maya. Properties like thickness, crease angle of seams, stretch and bend resistance all added to the power of cloth and the variety of simulations that can be created.

Syflex LLC is a company dedicated to providing the 3D animation market with superior simulation technologies. Landsend is a virtual shopping website; customers can login into the company website using the My Virtual Model™ to create their own model (3D mannequin) by submitting their appearance features such as height, weight, shoulder width, hair colour, etc. After creating their own model, customers can select the outfit from web store to drape onto the model. Users can also rotate the model to view the outfit in different sides.

The new 3D Studio Max plug in, ClothReyes, from Reyes Inforgrafica, was the world's first cloth simulator when it appeared on the market in 1997. It had such revolutionary features as tearable cloth and dynamic rigid body features, which it claims are still unsurpassed, taking its potential beyond fabric simulation. Reyes' approach to developing 3D software is aimed at making the technology converge with the practices of traditional garment production. Among other areas, it is the investigating way to forecast cloth behaviour; based on weave design, to aid the process of creating the fabric. It also adapts its advanced mathematical models of the Kawabata characterization system, used by the clothing industry for quality-control purposes. It is also addressing the perennial drape issue and working on sketching and virtual prototyping software, with the eventual goal – a realistic virtual catwalk.

The above advanced technologies in 3D garment simulation and CAD systems provide an effective way for pattern generation and 3D garment simulation for virtual visualization. However, the accuracy of garment fitting has not been verified experimentally. Besides, the accuracy of virtual garments presented by computer simulation might be affected by the complex of draping effects from fabric. It is believed that accuracy of garment fitting could be improved by establishing the relationship between body measurements and pattern measurements.

2.6 Pattern Design

Apparel pattern making is the process of transforming three-dimensional fashion designs into two-dimensional component pattern pieces (Koh 1997). This process contains a lot of procedures, construction formulae and methods. Precise pattern design is an important element in mass customization. The interrelationship between body measurements and pattern design are essential to garment fitting, pattern generation and 3D garment simulation.

2.6.1 Traditional Pattern Drafting Methods

The traditional methods for the acquisition of body dimensions are based on linear measurements, which are direct measurements from the human body by tape. Then such data was used for drafting or altering garment patterns with a predetermined technique (drafting procedures, formulae and methods).

One issue in the traditional pattern design is the visual assessment of body configuration by the practiced eye of the cutter. Gazzuolo et al (1992) pointed out that this intuitive approach has been codified in almost every pattern drafting and alteration practice. As many important dimensions of the pattern are under approximations by experienced people (Gauzzuolo et al 1992), this method for pattern drafting is not reliable and without experimental support.

Furthermore, the formulae in the traditional pattern drafting methods proposed by the tailoring experts may not be appropriated because each pattern parameter is generally derived from only one or two body measurements for pattern construction. However, each pattern parameter may correlate to several body measurements. In fact, body dimensions are very complex for measurements because it consists of many curvatures, concave and convex shapes, angles and slopes of human figure. Some of body measurements are interrelated, which would have significant effects on pattern prediction.

To address the shortcomings of traditional pattern drafting methods, Howland (1998) proposed to improve the fit of basic blocks to different body figures. He believed that this would help to reduce the frequency and simplify the procedures on altering the pattern into different styles and designs.

2.6.2 Prediction of Garment Pattern Based on Body Measurements

Garment pattern design is very important to garment fitting. With the well-developed body scanning system, accurate body measurements become readily available. Much work is now focused on improving garment pattern design based on body measurements.

The research about the relationship between body measurements and pattern design have been done for years. Brinson (1977) used somatometry methods to compare two processes of altering basic bodices and skirt. Hutchinson et al (1978) simulated the body form by polyethylene foam for moulding the body in order to assess the body shape and garment fit evaluation. Douty et al (1980 &1986) and Lesko (1982) used somatographs on women subjects to determine proportions of body segments, analyze body contour, and measure body angles so as to better understand the body size of women. The moulds were then cut into the form of two-dimensional shapes. From those shapes, an average shape was derived which was used to produce an average pattern.

Farrell et al (1983) altered two sets of pants by traditional and experimental methods for six women subjects for comparison analysis. Data points from somatographs were used to plot full-scale body contours, giving length along each line. Heisey (1985) proposed to develop a conceptual framework for studying the relationship between the two dimensional shape of a garment pattern and the three-dimensional form of the body geometrically. The comparison of the fit of two sets of attached basic bodices and skirts was done by Brackelsberg et al (1986). One set was altered by a traditional method that used body lengths and circumference and other set by an experimental method that added to the length and circumference measurements information about body angles from computer-drawn plots of the body profiles.

Gazzuolo et al (1992) predicted the garment pattern by photographic measurements of frontal and lateral views of the female body form through statistical regression model. Shen et al (1993) used somatographs (silhouette photography) to attempt to describe the human body shape graphically of female and then to produce the actual garment for checking the fit of the garment on the body.

Masuda et al (1997) also derived the prediction equation to obtain the gap lengths on the sides of the shoulder and upper chest blocks on the front trunk surface from the body measurements on female without making the pattern. The geometrical equations by Masuda et al (1998) were set up for determining the gap length on the front bodice in order to predict the front bodice tight fitting patterns without draping an individual. The gap length included several side lengths on the tight fitting pattern blocks over or under the corresponding side lengths of the body surface. These gap lengths were a key factor for covering the women's concave and convex shapes with flat sheeting. Researchers claimed that this was an indication of the void between the body surfaces and the tight fitting pattern.

The body measurement of stature, three girth items, four width items and four length items was obtained from the upper half body of Japanese adult males in order to understand physical type characteristics for making the plane figures by modeling (Momota 1998). The 3D torso curvatures of 110 ladies were recorded with a 3D digitizer and simulated by a triangulated polyhedron. The relation between plane development and 3D torso surface curvature was established by examining angle at concentrated vertices by Masuda et al (1998).

Tae et al (2000) developed a new direct pattern generation method using body garment shape matching process. Researchers transformed the three dimensionally measured anthropometric data to a convex shape body model by stereoscopy and adjusting its shape with considering the geometrical constraints of the underlying body model to obtain the optimum fit garment pattern. They developed a pattern flattening algorithm that flattens the three-dimensionally adjusted garment model into two-dimensional pattern with considering the anisotropic properties of the fabric.

Masuda et al (2003) compared the body surfaces between 101 young men and 110 young women in terms of two curvatures measurements. The understanding of the relation between the 3D torso shape of women and men and plane pattern making is very good for clothing design, however, the certain amount between body and pattern and the preference of fit from ladies are not considered.

The amount of ease allowance (customers' preference) on garment is also important for determining the optimum size of garment pattern from body measurements. Miyoshi et al (1995) revised the jacket pattern of the width across body, width across side panel, width across chest and width across back to evaluate the feeling from the wearers in stationary and moving conditions in order to predict the fit jacket pattern from the sensory testing. It proves that the relationship between body measurements, pattern design and garment ease (customers' preference) are very important for enhancing the garment fitting on loose-fitted garment. However, the comprehensive approach in this area is still limited. Last but not least, most previous research on pattern prediction from body measurements were only concerned on female body dimensions.

2.6.3 Garment Ease

Many researchers agreed that optimum garment ease are important to the garment appearance and fit (Reich 1991). The optimum amount of garment ease is an important parameter for mobility, appearance and fit as too much ease of allowance may block the movement and create wrinkles on garment surface, too little nearly "just fit" may create pressure sensation and also affect the body movement.

The optimum level of ease allowance is important for achieving the high satisfaction on garment fit for body movement unless the product is stretchable enough for wearing or is a tight-fitted style of garment. Unfortunately, guidelines on the optimum range of ease allowance are very limited.

Makabe et al (1988) has attempted to determine the part and quantity of necessary ease of clothing in the upper limb motion. The change of length surface and relief of the human body during the upper limb motion has been investigated by means of dermatograph, moire topography and modeling by gypsum tape. Janice et al (1996) has evaluated the amount of garment ease in protective garments for allowing the worker to move uninjured and being recognized as comfortable by the wearer. Ease allowance is over and above the main girth measurements. These allowances can differ from girth to girth, therefore, which should depend on girth, garment type, styling and fabric (Cooklin 1997).

Shu et al (1997) claimed that a lot of geometrical style lines could be drawn in accordance with the same measurement value from human body. That means the two-dimensional pattern may not fit the human body without considering the body shape. Therefore, they suggested that one should consider the ergonomics of human body in size-ease allocation.

Huck et al (1997) stated that ease quality is the difference between pattern dimension and human body, which is related to sensation intensity. Optimum ease could provide optimum garment fit to wearer as well as the appropriate subjective feeling on garment fit. In order to evaluate this element for creating precise garment patterns, subjective evaluation on garment fit is one of the feasible methods. It could further help to fully understand the customers' preference on subjective garment fitting. The optimum ease for motion was evaluated by the subjective testing (Miyoshi 1995 & Huck 1997) which improved the understanding of the effect of garment ease on the perceptions of the wearers in terms of garment fitting.

Musilova et al (2003) assessed the allowances on the looseness of ladies blouse, ladies polo coat and ladies coat. The authors assumed the body was in circle shape to calculate the horizontal dimension allowance between the bust level and clothing using the drafting formulae, which is used to helps the CAD system to create patterns. However, the precision of their assessment was affected by the accuracy of the pattern drafting formulae, which were not verified and the irregular shape of human body.

2.7 Garment Fit

Good fit is crucial to clothing comfort, appearance and consumer satisfaction. Momota et al (1998) conducted a survey of business suits on Japanese adult males. 607 Japanese adult males ranging from 20 to 59 in age were selected for investigation of the consciousness of the actual conditions of fit toward them. The results showed that more than half of the subjects concerned with ease movement and fit of ready-made suits at the shoulder. Anderson et al (2000) proposed to use the consumer fit preference data into an expert system to be used in decision-making involving fit.

2.7.1 Definition of Garment Fit

The definition of garment fit is not universal. Different views on garment fit have been expressed in the past (Yu et al 1998). Erwin (1969) stated that the elements of fit involve fabric grain, ease, line, set and balance. Park et al (1988) defined comfortable fit as garment not restricting the freedom of movement during wear. Stamper et al (1991) defined the well-fitted garments as comfortable to wear, allowing sufficient ease for freedom of movement, that are consistent with the current fashion, and that are free of undesirable wrinkles, sags, or bulges. Taya et al (1995) defined fit as how well the garment confirms to the three-dimensional human body. Meanwhile, Taya et al (1995) mentioned that the clothing shape is principally determined by five factors, these are clothing design, clothing material, clothing size, body size and body motion.

Hutchinson et al (1978) and Sieben (1998) pointed out that the hang of garments on the shoulders is critical to the fit of a garment. Hutchinson believed that the garments should fit perfectly between the neck and the horizontal line around the lower level of the armhole. If such areas and garment proportions were better understood, the main fitting difficulties would be overcome.

Stamper et al (1991) stated some critical requirements of garment fitting. Firstly, Garments should have sufficient ease for comfort in moving. Secondly, the neckline, collar, sleeve and pockets rest smoothly in their appointed position without gaping or binding. Thirdly, long sleeve style has sufficient ease at the elbow to allow the arm to bend comfortably and the sleeve should extend to the wristbond when the arm is relaxed. Fourthly, the garment is free of diagonal, vertical or horizontal wrinkles that are not part of the design.

Huck et al (1997) claimed that proper fit of apparel should depend on the relationship between the size of the garment and the size of the wearer. Madhu T. (2002) defined well-fitted garments as those comfortable to wear, allowing sufficient ease for freedom of movement, conforming to present-day fashion and free of wrinkles, sags or bulges. Body imperfection such as poor posture, grain of fabric affects poor garment hangs. Garment without any ease, viz. conforming exactly to the body would be uncomfortable to wear, as there is no room for reaching, sitting or even breathing. Too much ease would cause fullness and bulkiness of the garments. Therefore, a proper relationship between body and garment ease should be built in order to provide adequate fit to customers.

2.7.2 Subjective Fit Assessment

To understand the optimum garment ease for wearers and enhance the customer satisfaction in terms of fit and appearance, many researchers conducted a lot of subjective assessments on garment fitting. This not only ensures the quality of the garments, but also provides a yardstick to the manufacturers for product development. Moreover, it helps to generate precise garment patterns with the consideration of customers' preference.

Subjective fitting assessments were carried out by Shim et al. (1993), who conducted a study with respect to the satisfaction of apparel fit for the women 55 years and older. The area of the study included the factors such as style, color, fabric, sizing, definition and ordering information. In second part of Shim et al (1996) study, the overall satisfaction and dissatisfaction of women 55 years and older with the fit of ready-to-wear in terms of the demographics, clothing buying practices, and self-reported clothing problem locations were examined.

Feather et al (1996) studied 503 female collegiate basketball players in terms of body cathexis, body form, garment fit satisfaction, uniform design preferences and demographic characteristics towards the fit design of basketball uniform.

The subjective assessment should evaluate at different postures and under body movements. Huck et al (1997) evaluated the subjective wearing sensation of the protective overall. Wearers were required to follow the procedure of exercises such as kneel on left knee, duck squat, stand erect etc. They were required to fill in the scaling list with pair of description such as stiff and flexible, tight and loose etc from rating 1 to 9. 1 was equal to stiff and 9 was equal to flexible. Anderson et al (1998) has proposed to investigate the female consumers in five focus groups for developing a model so as to understand fit preferences for female consumers.

Aldrich et al (1998) also conducted subjective fitting assessment for women's tailored jackets. In their study, a subject with a light clothing was required to perform a series of sitting and standing postures. In standing postures, the subjects were required to perform upright standing, ergonomic flexion, natural flexion (midway), maximum natural flexion, lateral flexion, ergonomic lateral flexion and maximum natural flexion. In sitting postures, the subjects were required to perform upright sitting, ergonomic flexion, natural flexion (midway) and maximum natural flexion. The other postures included trunk flexion and rotation, trunk hyperextension, kneeling and bending, the different positions of the right arm in a vertical plane and the different positions of the lower arm were examined. Those postures were likely to be performed by business women in their real activities. Photograph were taken and grouped according to different segments of the body such as trunk, upper arm and lower arm, and compared visually.

Although the subjective assessment tends to be inconsistent and unreliable, but it is still important for manufacturers to understand the fit requirements of the wearers to a particular garment in terms of personal perception and garment appearance when hanging on the body.

2.7.3 Objective Measurement of Garment Fit

Different objective methods have been proposed or developed for assessing the garment fit more precisely and accurately. These include fitting index, symmetrized dot pattern, waveform of clothing, moiré topography and video image. In the following sections, these various methods of objective garment fit evaluation are described and discussed.

2.7.3.1 Fitting Index

In order to predict and measure the garment fit for wearers, Taya et al. (1995) proposed a fitting index. The index is based on the measurement of the space between the body and clothing, which can be obtained on a dummy.

Ng et al (1996) suggested four different levels of fit, namely linear dimension, the cross-section area, the volume and the overall. Correspondingly, Linear Index, the Cross-

Sectional Index, the Volume Index and the Signature Curve were proposed to provide measures of the different levels of fit. However, these indices have not been verified experimentally.

2.7.3.2 Symmetrized Dot Pattern (SDPs)

Taya et al (1995) applied the Pickover's symmetrized dot pattern (SDPs) to grasp the subtle difference in clothing shape. As patterns having symmetry elements can make features more obvious to the observers, clothing shape can be quantified based on the dot patterns.

2.7.3.3 Waveform of the Clothing

Waveform of the space between body and clothing was used to analyse garment fit by Taya et al (1995). Three-dimensional clothing shapes were measured at the equal intervals in the direction of the body axis with standard posture. The amplitudes of clothing waveform were analyzed by using the probability density spectra and the symmetrized dot pattern (SPD).

Furthermore, the wavelet analysis was applied to extract the characteristics of clothing waveform for evaluating garment fit. Taya et al (1996) claimed that the wavelet analysis could detect any small variations in the clothing waveform by a change of materials or size.

The wavelet analysis is potentially a good method for garment fit evaluation. However, the effects of body motion toward the garment fitting, the relationship between the body dimensions and the proper proportion of the garment design, and the subjective wearing comfort could not be considered in the method.

2.7.3.4 Video Image

Another objective evaluation method for garment fit is to use the video camera to capture images from human subjects, then use digital image processing techniques to detect body features (Pfister et al 1991).

The image of slashed garments is video-captured and analyzed to assess the apparel fit. Kohn et al (1998) applied this method to study the effect of posture on the fit of garments worn by mature women between the age of 55 and 65.

2.7.3.5 Limitations of Existing Objective Methods for Evaluating Garment Fit

Although a number of objective methods for evaluating garment fit have been proposed, in applying these methods, there is still a lot of limitation. The difficulty lies in how to accurately and efficiently capture the garment surface, which may be folded or wrinkled.

2.7.4 Fabric Properties to Garment Fitting

Material property is one of the important parameters related to garment fit. Fabric properties have been considered for pattern generation for enhancing garment fitting. Aisaka et al (1985) used the physical properties of fabric to develop an estimating method of the three-dimensional shape of made-up garment in order to develop a suitable planar pattern information processing method. Okabe et al. (1988) used the mechanical characteristics of fabric for three-dimensional dress simulations.

Fabric properties such as bending rigidity, the shear resistance, elongation of fabric-self-weight have been used for predicting the silhouette of flared skirts by multiple regression analysis.

Investigation of the relationships between fabric properties, pattern construction, and the fit of knit underwear was proposed by Rodel (1998) for developing construction rules of knit underwear for shortening the production times and improving the product quality.

The effects of fabric properties on garment fitting are related to fabric draping. The draping of fabric becomes more complex when the body is moving. The draping phenomenon requires complicated mathematical simulation (Yamakawa 1996). The complete modeling of the draping effects has still not been realized due to the complexity of drape modeling. This is still a major challenge for 3D virtual garment simulation.

2.7.5 Simulation of Garment Fit

Simulation of garment fit is one way of predicting the garment fit and appearance before the real garment is made. Matsuda et al (1994 & 1995) developed a graphic method to simulate garment fitting on human body in various posture. In their work, a human body was divided into six columns, which were then subdivided into twelve parts. The results showed that such method could successfully represent a garment form that fits well the model body for every type of clothing.

Ng et al (1995) developed an Algebraic Mannequin for simulating garment fit. The shape of this Algebraic Mannequin is determined by a set of shape parameters such as girth, width, and length, and therefore may be adjusted to simulate a specific body. Virtual garments may be put on the Algebraic Mannequin for fitting analysis.

2.8 Remaining Issues

Although there have been much research and development concerned with pattern design, garment fit and appearance, many issues are still not fully addressed. The followings are a summary of the remaining problems after reviewing the above literatures.

1) Many of the anthropometric data sets are outdated. With the availability of 3D body scanning technology, anthropometric surveys should be conducted periodically for different groups of populations.

2) Although there are commercial CAD software capable of 3D garment design and converting 3D garments to 2D patterns; such systems do not work well with loose-fitting garments as they involve complex garment draping, which can still not be accurately modeled.

3) Although there are traditional pattern drafting methods (Aldrich 1997; Cham 1988), which can generate garment patterns based on body measurements. Such pattern drafting methods have not been verified experimentally in terms of garment fit. Hence, it is doubtful whether such traditional methods and techniques can be directly used for creating automated pattern generation systems.

4) Although there have been much work related to pattern design (Hutchinson et al 1978; Heisey 1985; Gazzuolo et al 1992; Miyoshi et al 1995; Matsuda et al 1997; Matsuda et al 1998; Tae et al 2000;), past work was limited to generally tight-fitting garments. There is no systematic study on the relationships between body dimensions, customers' fitting preference and garment pattern.

Chapter 3
Experimental and Results

Chapter 3

Experimental and Results

3.1 Introduction

In order to establish interrelationships between shirt pattern design, fitting perceptions and human body so as to automate the drafting of shirt patterns from body measurements and fitting requirements, it is necessary to quantify and accurately measure pattern parameters, fitting perceptions and body measurements.

In this project, human subjects were measured using a Techmath 3D laser scanner. The technical features and scanning procedure of the 3D body scanner are described in this Chapter.

It is also important to ensure that the human subjects invited for this investigation are representative to a target population, which is Oriental male. The Japanese and Chinese national standards were therefore referred in terms of the key body measurements and compared those with the key body measurements of the human subjects in this investigation. As will be seen from the comparison shown in this Chapter, the human subjects are representative of the Oriental male population.

As to the men's shirt pattern, thirty-three key pattern parameters were necessary and sufficient to specify the geometry of the patterns. These pattern parameters are hereby defined and the procedures of measuring these parameters are reported.

This Chapter also reports on the procedure and rating scale of the fitting perceptions of both tailoring experts and wearers themselves, when the human subjects worn the shirts and underwent a sequence of activities.

3.2 Nomenclature

B_1	= Body height
B_2	= Head height
B_3	= Distance neck to hip
B_4	= Neck diameter
B_5	= Mid neck girth
B_6	= Side upper torso length
B_7	= Torso width
B_8	= Total torso girth
B_9	= Cross shoulder over neck
B_{10}	= Cross shoulder
B_{11}	= 1/2 Shoulder width
B_{12}	= Shoulder angle L (°)
B_{13}	= Shoulder angle R (°)
B_{14}	= Cross front width
B_{15}	= Breast width
B_{16}	= Neck to waist over bust
B_{17}	= Neck front to waist over bust
B_{18}	= Bust points around neck
B_{19}	= Bust point to neck
B_{20}	= Chest band
B_{21}	= Midriff girth
B_{22}	= Cross back width

B_{23}	= Back width
B_{24}	= Neck to underarm back
B_{25}	= Back length
B_{26}	= Back length over shoulder blade
B_{27}	= Distance armpit-waist
B_{28}	= Waist to hip back
B_{29}	= Waist girth
B_{30}	= Waist to hip
B_{31}	= Hip girth
B_{32}	= Arm length to neck back
B_{33}	= Arm length to neck
B_{34}	= Arm length
G_1-G_{33}	= Defined in Fig. 3.41
n	= number of panel
1.96	= the critical value at level of significance at α=0.05
σ	= standard derivation of each question
E	= maximum allowable error of estimate

3.3 3D Body Scanning

Precise body measurement is important for achieving individual fit in pattern drafting. In this study, human subjects were scanned by a Techmath Laser Body Scanner installed in the Clothing Industry Training Authority (CITA) of Hong Kong. The scanner was used for its accuracy, speed and relatively good popularity in the industry. It was made available for the study thanks to the support of CITA.

3.3.1 Techmath Laser Body Scanner

Techmath Laser Body Scanner is one of the leading three-dimensional laser body scanners in the world. Producer claims that the scanner is very accuracy and reliability. The current body scanner for clothing applications is VITUS/smart, designed for mass customization applications. The scanning time is between 10 to 20 seconds. It is a modular system with four columns, each column consists two CCD-cameras and a laser, with a measurement volume of 210 cm x 100 cm x 100 cm. External dimensions are 310 x 250 x 185 cm. The resolution of this body scanner is 1 mm in depth, 2 mm vertically, and 1 mm horizontally. From the scanner, 3D-models are created that consist of up to 2 million points and the accuracy is $\pm$1 mm (2, 3, 4). This body scanner contains 4 laser bars. Each bar will project the laser toward the subject's surface simultaneously. Fig. 3.1 shows the platform for body scanning, a subject standing on the fixed position, 4 laser bars and a red laser light (website from Techmath Co.).

Fig. 3.1 The Techmath Laser Body Scanner

Source: http://www.human-solutions.com/scanworx

Fig. 3.33 shows a screen output of Techmath Laser Body Scanner with 95 body measurements. These body measurements are listed on the right hand side of the computer screen. The upper body measurements such as the neck girth, cross back width, bust point to neck, are important data for shirt pattern construction. There are totally 34 upper body measurements considered for the study. These include body height, neck girth, chest girth, waist girth, hip girth, arm length etc. and were identified as B_1 to $B_{34.}$ The definitions of body measurements are illustrated in Figs 3.2 to 3.32. Each red line indicates a particular body measurement of subject obtained from the laser scanner.

Fig. 3.2 Body Parameters B_1

(Body height) and B_2 (Head height)

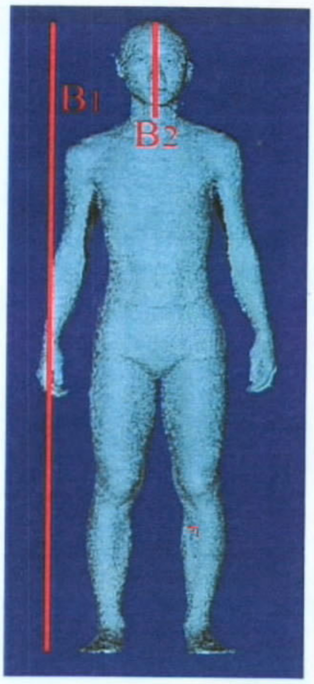


Fig. 3.3 Body Parameter B_3

(Distance neck to hip)

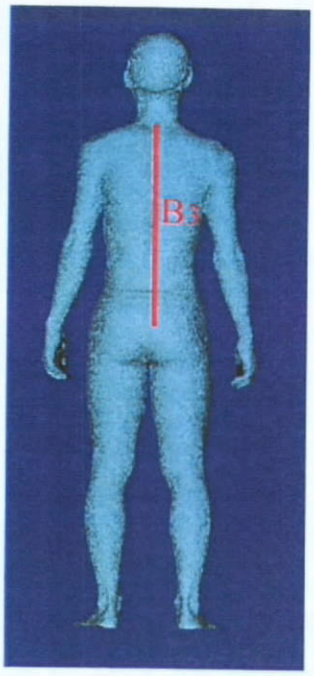


Fig. 3.4 Body Parameters B_4

(Neck diameter)

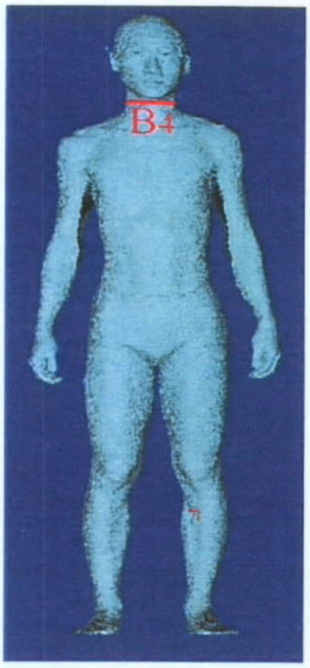


Fig. 3.5 Body Parameter B_5

(Mid neck girth)

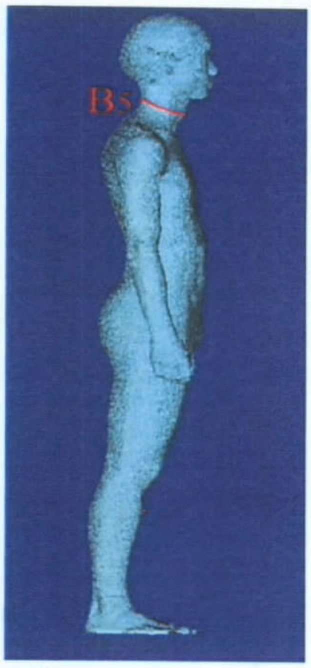


Fig. 3.6 Body Parameters B_6

(Side upper torso length) and B_7 (Torso width)

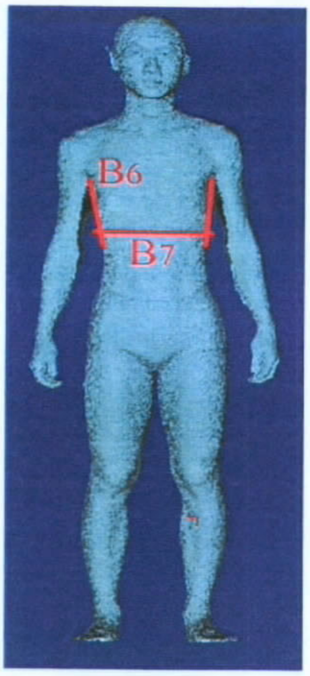


Fig. 3.7 Body Parameter B_8

(Total torso girth)

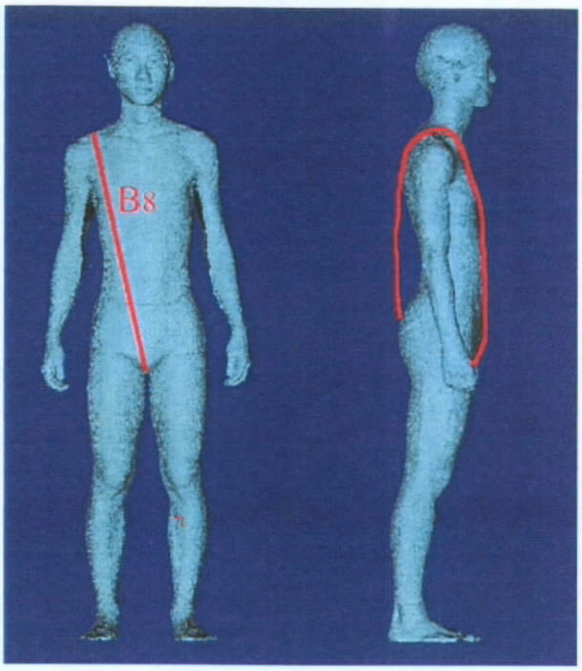


Fig. 3.8 Body Parameters B_9

(Cross shoulder over neck)

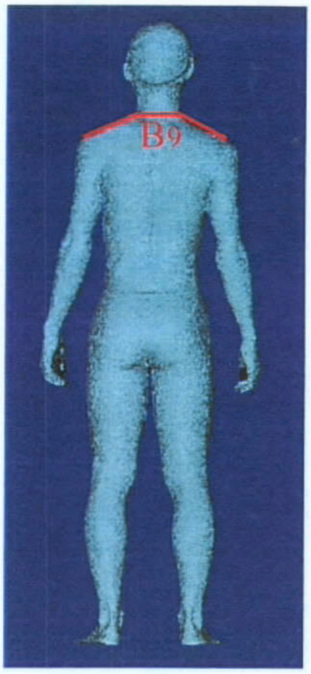


Fig. 3.9 Body Parameter B_{10}

(Cross shoulder)

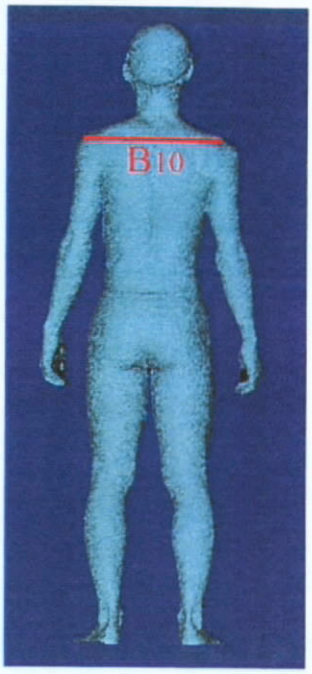


Fig. 3.10 Body Parameters B_{11}

(1/2 Shoulder width)

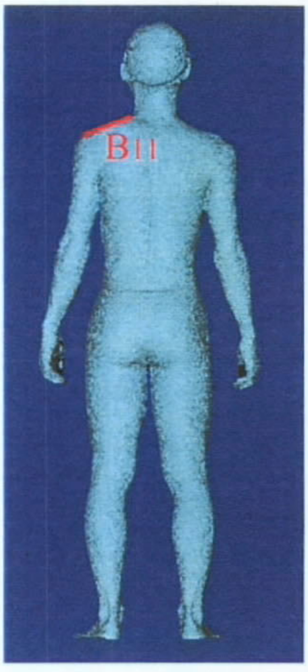


Fig. 3.11 Body Parameter $B_{12, 13}$

(Shoulder angle L and R (°))

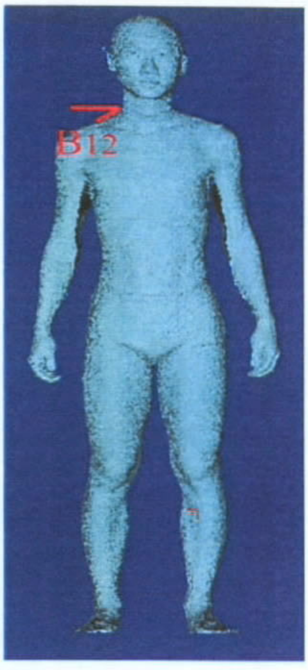


Fig. 3.12 Body Parameters B_{14}

(Cross front width)

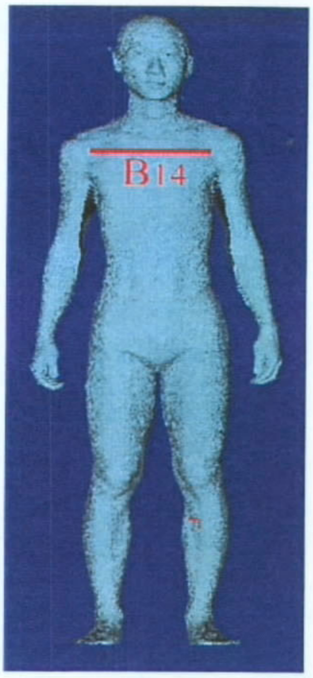


Fig. 3.13 Body Parameter B_{15}

(Breast width)

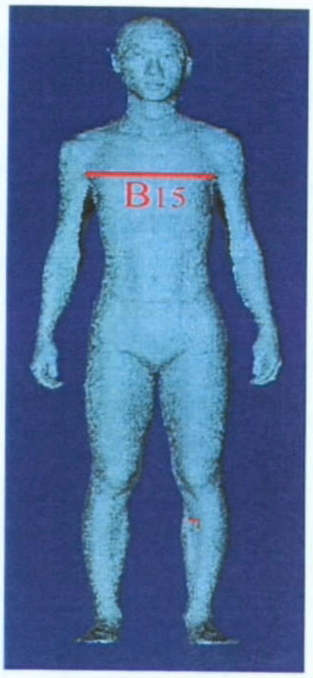


Fig. 3.14 Body Parameter B_{16}

(Neck to waist over bust)

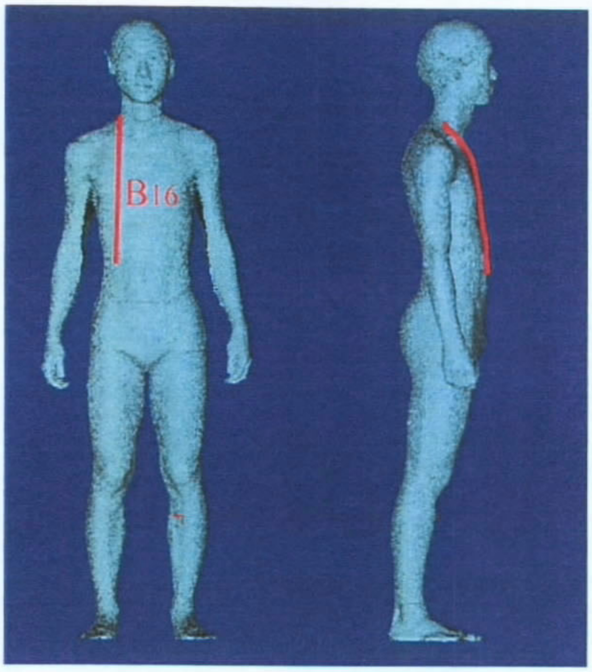


Fig. 3.15 Body Parameter B_{17}

(Neck front to waist over bust)

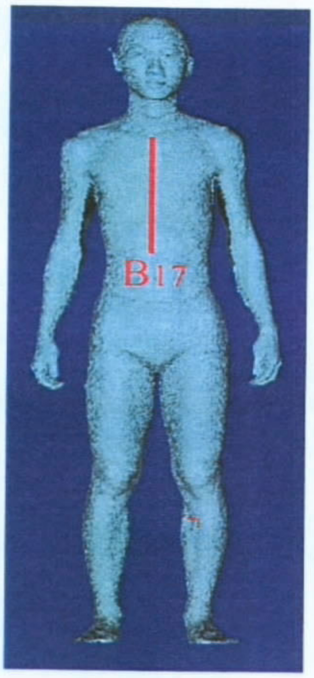


Fig. 3.16 Body Parameter B_{18}

(Bust points around neck)

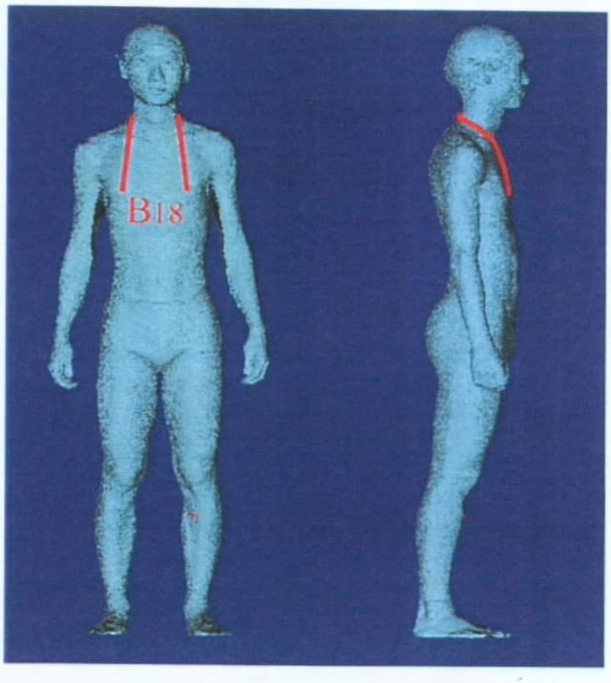


Fig. 3.17 Body Parameter B_{19}

(Bust point to neck)

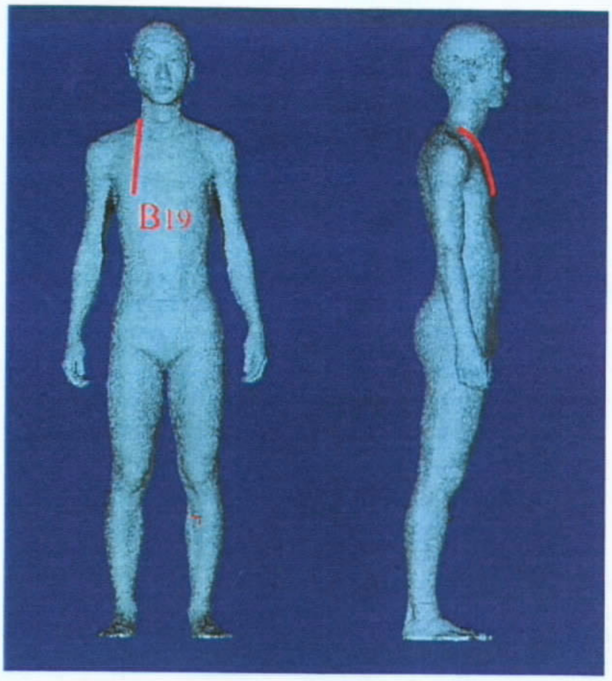


Fig. 3.18 Body Parameter B_{20}

(Chest band)

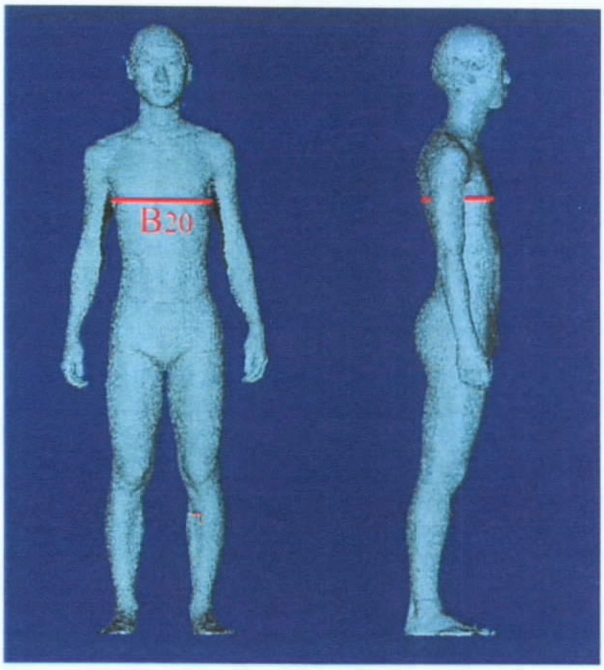


Fig. 3.19 Body Parameter B_{21}

(Midriff girth)

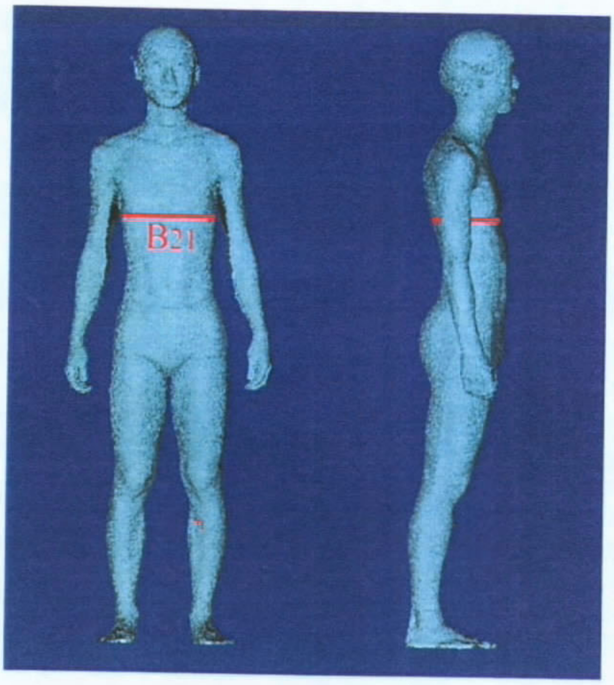


Fig. 3.20 Body Parameter B_{22}

(Cross back width)

Fig. 3.21 Body Parameters B_{23}

(Back width)

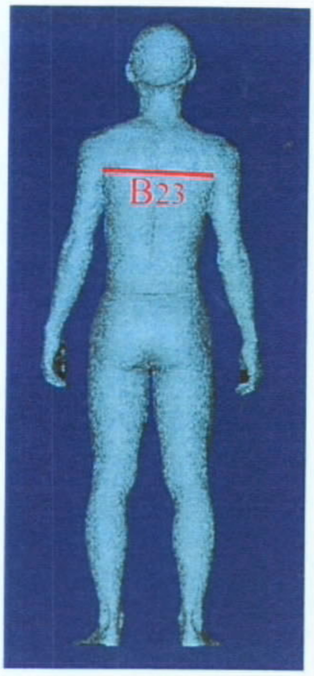


Fig. 3.22 Body Parameter B_{24}

(Neck to underarm back)

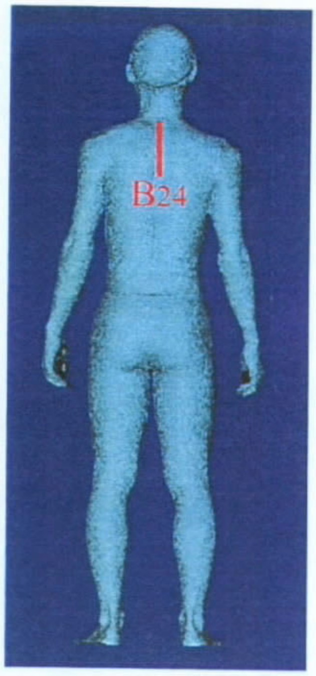


Fig. 3.23 Body Parameter B_{25}

(Back length)

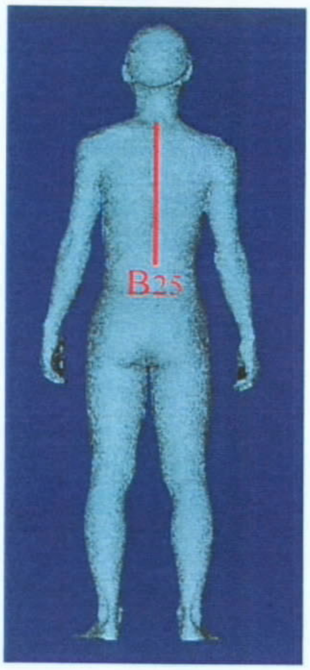


Fig. 3.24 Body Parameter B_{26}

(Back length over shoulder blade Back length)

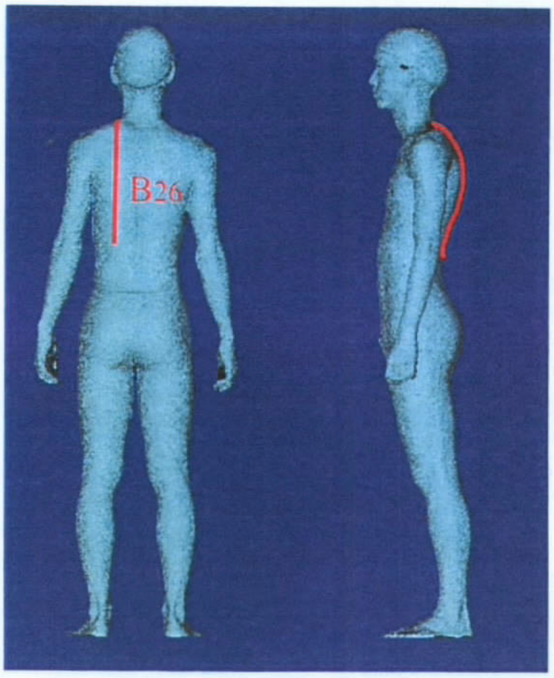


Fig. 3.25 Body Parameter B_{27}

(Distance armpit-waist)

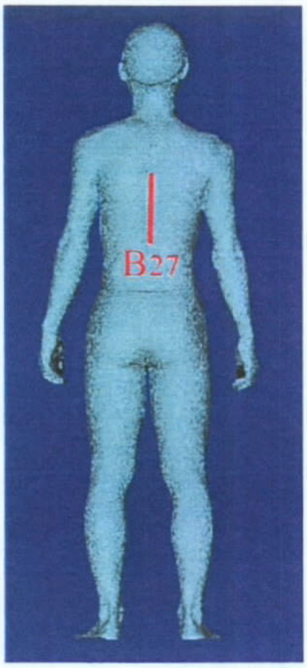


Fig. 3.26 Body Parameter B_{28}

(Waist to hip back)

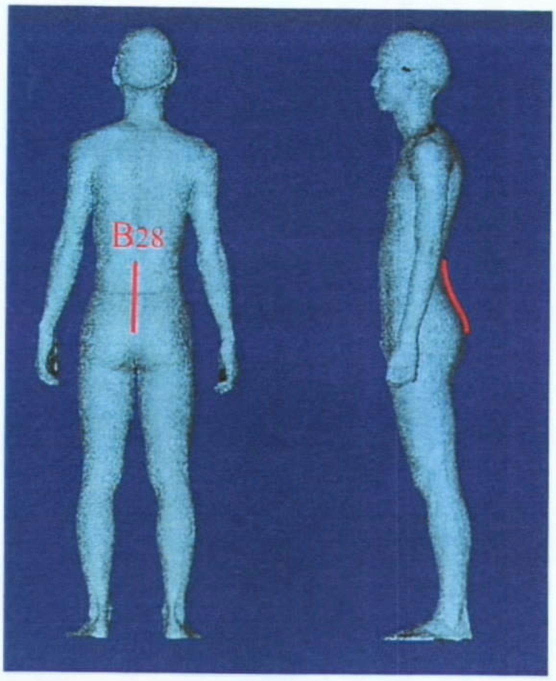


Fig. 3.27 Body Parameter B_{29}

(Waist girth)

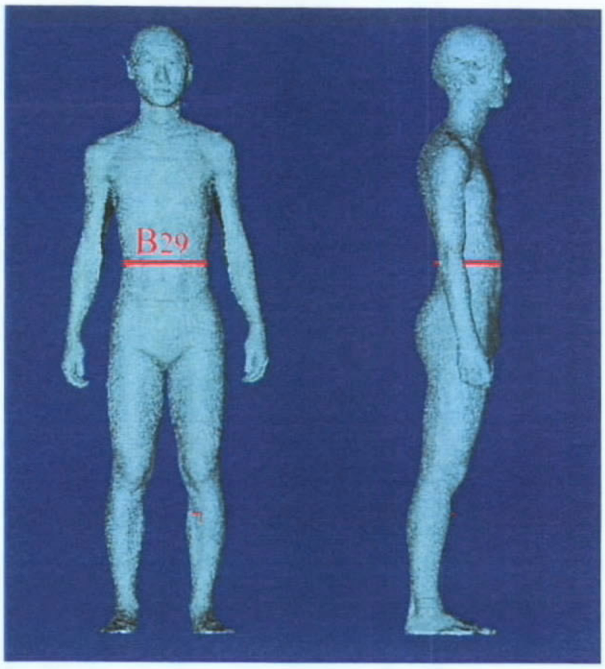


Fig. 3.28 Body Parameter B_{30}

(Waist to hip)

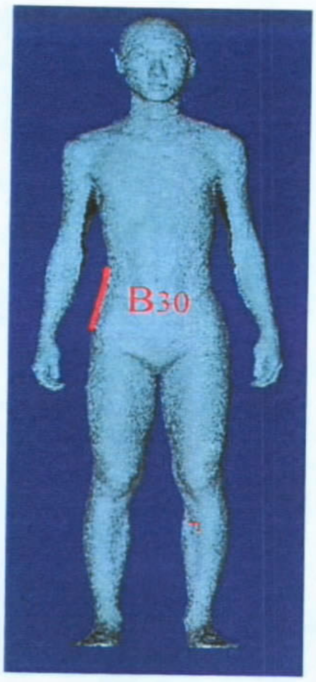


Fig. 3.29 Body Parameter B_{31}

(Hip girth)

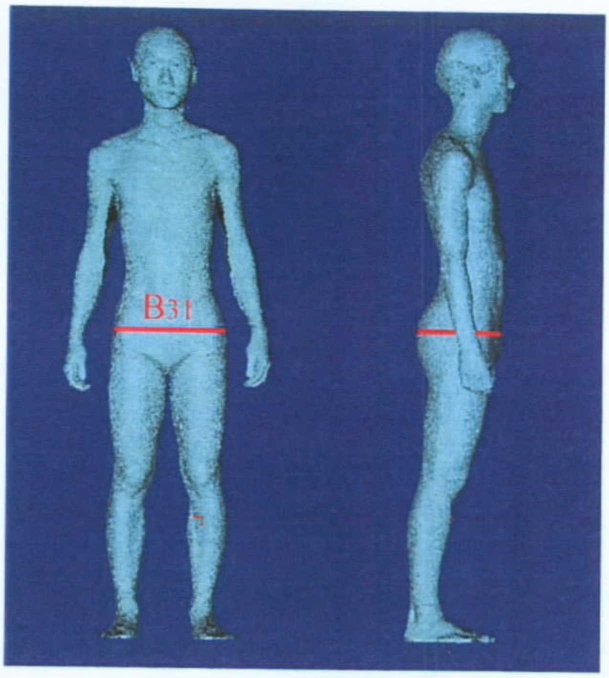


Fig. 3.30 Body Parameter B_{32}

(Arm length to neck back)

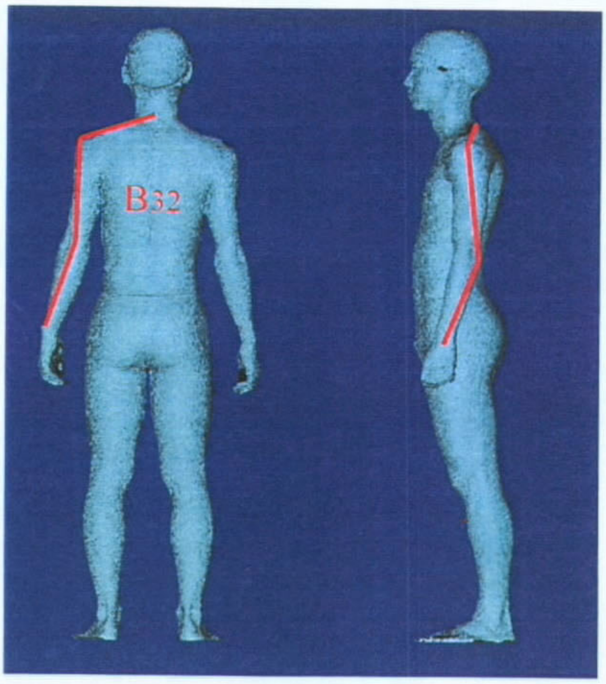


Fig. 3.31 Body Parameter B_{33}

(Arm length to neck)

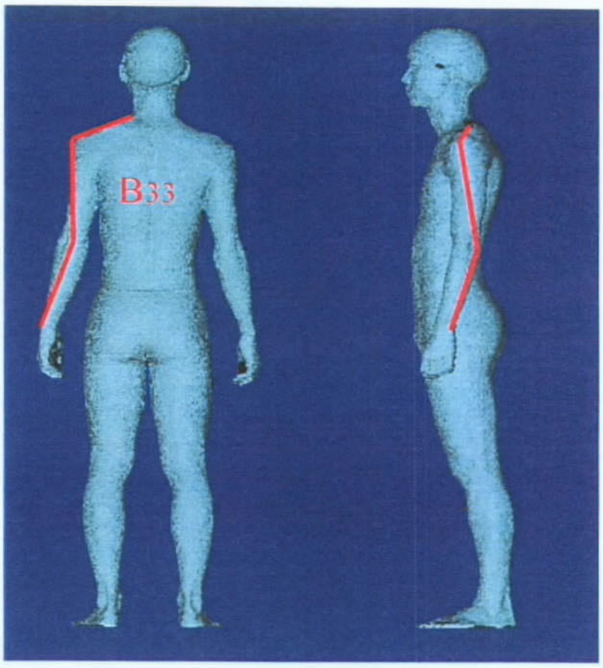
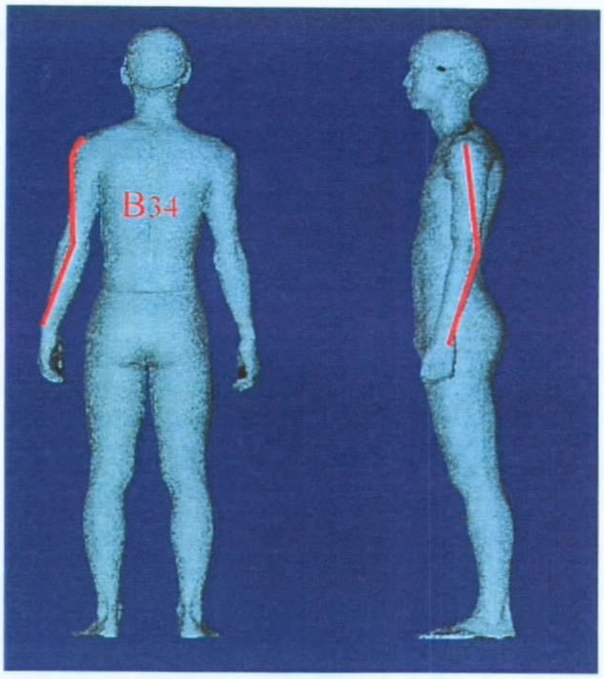


Fig. 3.32 Body Parameter B_{34}

(Arm length)



3.3.2 Scanning Procedure

The subjects were required to wear a white knitted underwear and a white hat before scanning. Inside the dark scanning room, subject stood straight at the marked standing location on the platform. The feet of each subject should be vertically parallel to the shoulder. Their hands were required to be put apart from his waist level for around 5 to 7 inches. When the scanner is switched on, the 4 laser bars project the laser beam onto the subject's body from top to bottom within 10 seconds. 95 body measurements were finally listed out on the right hand side of the computer screen as shown in Fig. 3.33. The scanned body can be viewed from 4 different angles as shown in Fig. 3.34.

Fig. 3.33 The Outputs of Measurements Data from Techmath Laser Scanner

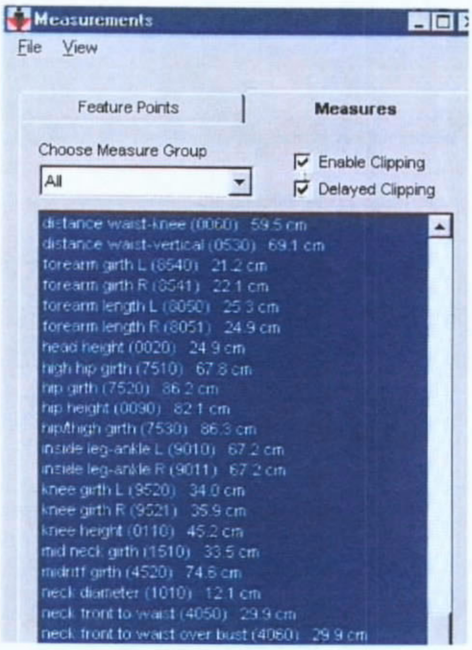
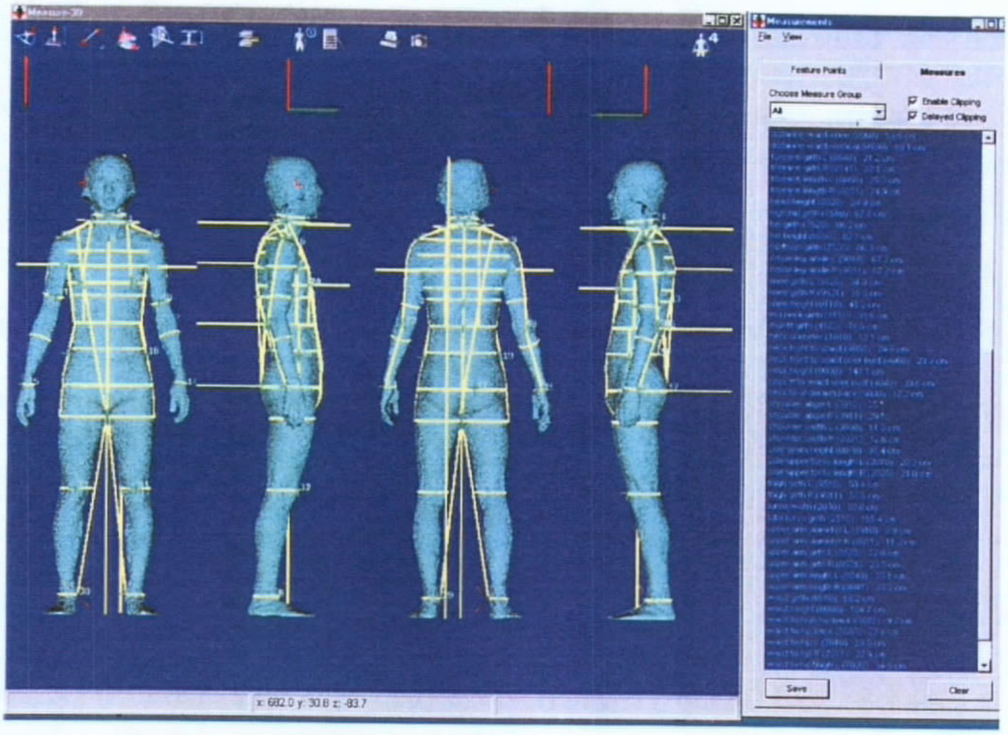


Fig. 3.34 The 4 Views of Body Scanning Image



3.3.3 Comparison between Measurements from the Laser Scanner and from Manual Measurements

The accuracy of the body measurements from the scanner was verified with manual body measurements. Table 3.1 compares some common body measurements from the 3D laser scanner and those from manual measurements such as neck girth, chest girth, hip girth, sleeve length, cross shoulder etc. Those measurements are commonly used by tailors and tailoring experts' formulae. The maximum deviation of those body measurements is 0.2 cm. As can be seen, the accuracy of the 3D body scanner can be assured.

Table 3.1 Differences between Body Measurements from 3D Laser Scanner and Manual Measurements

Body Parameters	Descriptions	Maximum Differences (cm)
B_1	Body height	0.2
B_5	Mid neck girth	0.1
B_{10}	Cross shoulder	0.1
B_{11}	1/2 Shoulder width	0.1
B_{14}	Cross front width	0.1
B_{15}	Breast width	0.2
B_{20}	Chest band	0.2
B_{21}	Midriff girth	0.2
B_{22}	Cross back width	0.2
B_{23}	Back width	0.2
B_{25}	Back length	0.2
B_{29}	Waist girth	0.2
B_{30}	Waist to hip	0.2
B_{31}	Hip girth	0.2
B_{32}	Arm length to neck back	0.2
B_{33}	Arm length to neck	0.2
B_{34}	Arm length	0.2

3.4 Selection of Human Subjects

The human subjects in this study should be representative to the target population. In this study, the target population is Oriental male adults. In selecting the human subjects, the sizes covered in the Japanese Industrial Standard and Chinese National Standard are considered.

3.4.1 Japanese Industrial Standard (JIS L4117: 1992)

The first industrial standard related to size of menswear is Japanese Industrial Standard (JIS L4117: 1992), which is the finished size standard of men's dress shirt. It has five types of size classifications according to shirt shape. Those are type Y, A, AB, B and E.

In the standard, "Type Y is called taper or slim type: the type of dress shirts which are cut and sewn to the shape of tightened waist". "Type A of dress shirt are designed and sewn to a balanced form with the standard chest girth and waist girth". "Type AB is so designed and sewn that the chest and waist girth are larger than those of Type A, and that the difference between chest girth and waist girth is smaller than those of type A". "Type B is of 43 cm to 46 cm collar girth and is so designed and sewn that each size of chest girth and waist girth is larger than that of Type AB for each size of collar girth and the difference between chest girth and waist girth is smaller than that in type AB". "Type E is of 43 cm to 46 cm collar girth and is so designed and sewn that each size of chest girth and waist girth is larger than that of Type B for each size of collar girth and there is no difference between chest girth and waist girth".

The 5 different shapes and styles of men's shirt described in standard are not so relevant to the present study, but the body sizes the standard covers give an indication of the size range of Japanese male population. Table 3.2 lists the sizes of the 5 different types of men's dress shirt in terms of collar girth, shoulder width, chest girth and waist girth.

Table 3.2 Summary of Shirt Size in 5 Different Types (in CM)

Shirt Type	Information reference (Standard finished size)			
	Collar girth	Shoulder width	Chest girth	Waist girth
Y	35-42	41-49	94-118	78-108
A	35-43	42-50	95-122	82-116
AB	36-43	43-51	102-123	90-117
B	43-46	49-52	122-130	116-126
E	43-46	50-53	124-132	130-132

3.4.2 Chinese National Standard

The Chinese national standard, Chinese Size Designation of Clothes (1998-06-01), describes sizes of clothes in four categories according to the waist drop, i.e. the amount difference between the waist girth and chest girth, which are designated in the letters Y, A, B and C. The detailed size measurements are listed in Table 3.3. As can be seen, the neck girth ranged from 33.4 to 43.6 cm. This may not be the entire size ranges of neck girth in the China population, but should cover the majority of Chinese as it is a national statistic. There is unfortunately no available information about the size distributions of male citizens in Hong Kong, but they should be similar to Japanese and Chinese national statistics.

Table 3.3 Size Designation of Clothes, 1998-06-01 (in CM)

Chest girth (cm)	Y (Waist drop) 17-22cm	A (Waist drop) 12-16cm	B (Waist drop) 7-11cm	C (Waist drop) 2-6cm
	Neck girth	Neck girth	Neck girth	Neck girth
72		32.8	33.2	
76	33.4	33.8	34.2	34.6
80	34.4	34.8	35.2	35.6
84	35.4	35.8	36.2	36.6
88	36.4	36.8	37.2	37.6
92	37.4	37.8	38.2	38.6
96	38.4	38.8	39.2	39.6
100	39.4	39.8	40.2	40.6
104			41.2	41.6
108			42.2	42.6
112				43.6

Considering the Japanese and Chinese standards together, men's neck girth is ranged from 32.8 cm to 46 cm, the shoulder width from 41 cm to 53 cm, the chest girth from 72 cm to 132 cm and the waist girth from 78 cm to 132 cm.

3.4.3 Human Subjects

In order to evaluate the men shirt fitting and obtain the body measurement data, 60 male subjects varying from slim to obese were invited for the study. Unfortunately, one of the subjects left Hong Kong during the course of the study, and hence only 59 human subjects participated the entire process of the study.

The criterion of male subject selection is to cover a full range of sizes distribution of men dress shirt as specified in the industrial standard. The age of subjects was not a critical factor for subject selection.

According to the tailors, pattern technicians, manufacturers and designers, the sizing system of men's shirt is represented by the neck size and chest size in ready-to-wear market. Moreover, the sizing systems for men's garments in Japanese Industrial Standard, (JIS L4004: 2001) and International Standard Organization, (ISO 4415 – 1981) stated that the control dimension of formal and uniform shirt is neck girth. In addition, Japanese Industrial Standard for dress shirt (JIS L4117: 1992) and "Size Designation of Clothes from China (1998-06-01)" show that the size designation of dress shirt also includes the shoulder width, chest girth and waist girth.

In this project, the subjects were adult men who wear shirt for working. The definition of man from "Japanese Industrial Standard (JIS L4004: 2001)" is a male subject whose growth in height is finished.

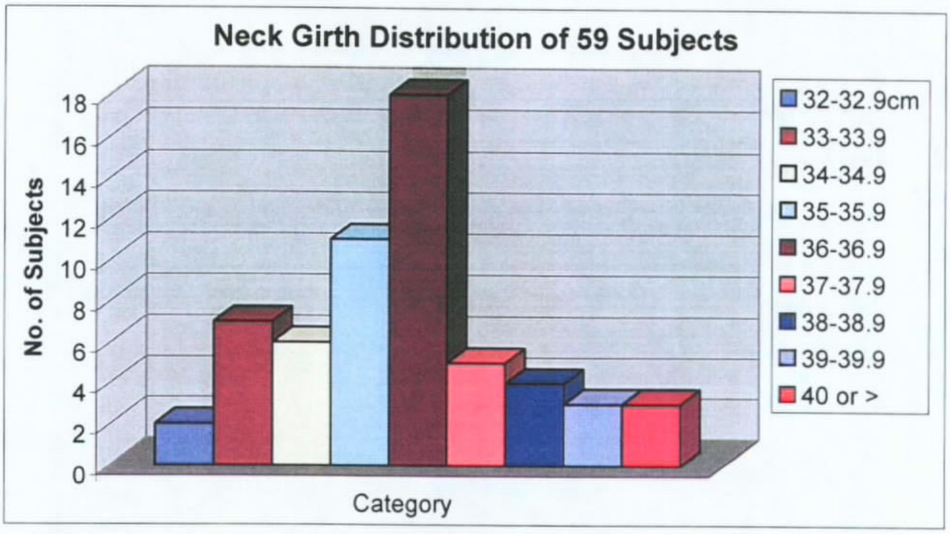
Based on the above considerations of international standards, neck girth of male subjects in this study was a key element for subject selection. The second important elements in subject selection were the shoulder width, chest girths and waist girths.

The human subjects were scanned using the Techmath Laser Scanner. Appendix I lists the body measurements of the human subjects from the laser scanner. The distribution of neck sizes, shoulder width, chest girths and waist girths of these 59 male subjects compared with the size ranges shown in the Japanese and Chinese standards.

3.4.3.1 Neck Size

The neck girth distribution of 59 subjects measured from body scanner is ranged from 32.2 cm to 43.3 cm. Fig. 3.35 shows the distribution of the neck girth. The interval of each category of neck girth distribution is 1 cm. The mode interval of the neck girth measurement is between 36 cm and 36.9 cm, with 18 subjects in this category. Owing to the difficulty in recruiting large human subjects, there are more subjects with small neck size. In general, however, the neck girth of the subjects covers the ranges indicated in the two international standards, which is from 32.8 cm to 46 cm.

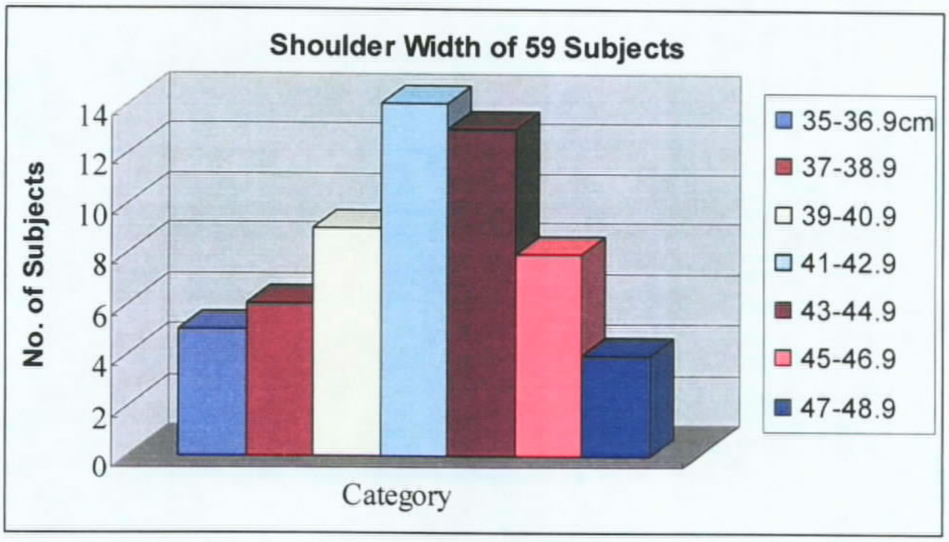
Fig. 3.35 Neck Girth of 59 Subjects from Body Scanner



3.4.3.2 Shoulder Width

The shoulder width of 59 subjects measured by the body scanner ranged from 35.1 cm and 48.6 cm. This range is slightly smaller than those specified in the Japanese Standard, which is from 41 to 53cm. Fig. 3.36 shows the distribution of the shoulder width of these 59 subjects. The interval of each category of shoulder width distribution is 2 cm. The mode interval of shoulder width measurement is from 41 cm to 42.9 cm and there are 14 subjects in this category. The shoulder width of human subjects has an approximately normal distribution.

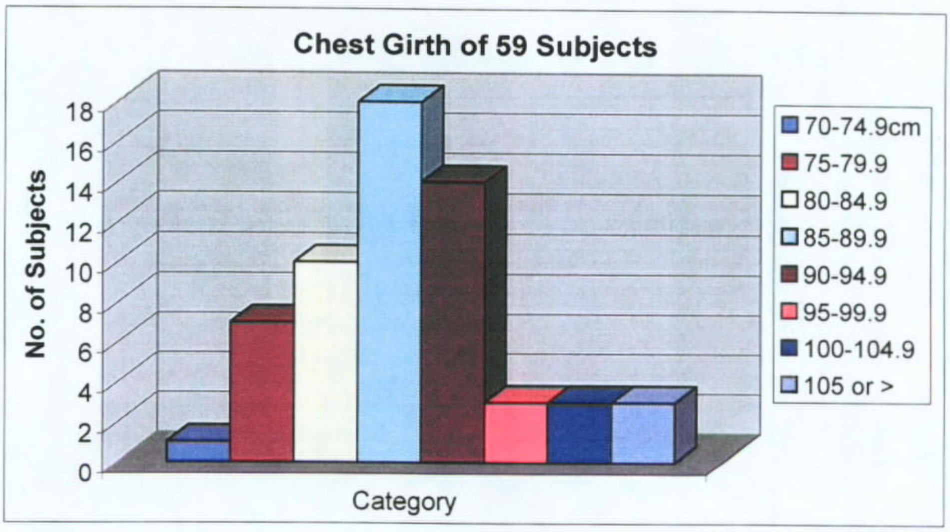
Fig. 3.36 Shoulder Width of 59 Subjects



3.4.3.3 Chest Girth

The chest girth of 59 subjects ranged from 72.7 cm and 118.9 cm, which is also slightly thinner than those specified in the Japanese Standard which is from 94 to 132. This is probably because of the difficulty in recruiting large size human subjects for the study or Hong Kong Chinese are generally thinner than Japanese. Fig. 3.37 shows the distribution of the chest girth of the 59 subjects. The interval of each category of chest girth distribution is 5cm. The mode interval of chest girth measurement is from 85cm to 89.9cm and there are 18 subjects in this category.

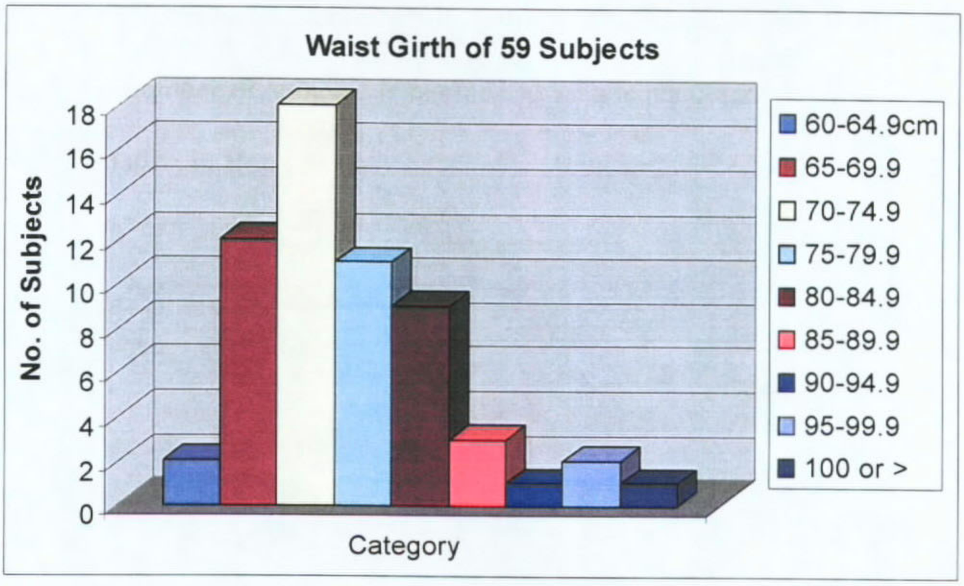
Fig. 3.37 Chest Girth of 59 Subjects from Body Scanner



3.4.3.4 Waist Girth

The waist girth of 59 subjects ranged from 63.9 cm to 104.5 cm, which is also slightly smaller than those specified in the Japanese Standard which is from 78 to 132. Fig. 3.38 shows the distribution of the waist girth of those 59 subjects. The interval of each category of waist girth distribution is 5 cm. The mode interval of waist girth measurement is the group from 70 cm to 74.9 cm and there are 18 subjects in this category.

Fig. 3.38 Waist Girth of 59 Subjects from Body Scanner



Although the size ranges of human subjects in terms of shoulder width, chest girth and waist girth are slightly smaller than those specified in the Japanese Standard, these 59 subjects are still considered as a good redid not cover the requirement on the largest size measurement from two standards. However, the size distribution of 59 subjects still could be valid for representing the men's size distribution in Hong Kong. This is because firstly, the survey on men's size distribution in Hong Kong is limited. There is no evidence to show that the mentioned girth measurements should be covered such extreme large in size. Secondly, the Japanese standard is according to different shapes of men's dress shirt. However, the shape of shirt in this study is common and fitted to subjects. Thirdly, there is difficult to invite subjects for experiment. Last but not least, the neck girth distribution of subjects fulfills the size range requirement of two standards. Therefore, the number of subjects is claimed to be adequate and valid for representing the male population in Hong Kong.

3.5 Dress Shirt Samples and Pattern Measurements

In this project, it is necessary to produce shirt samples and quantify shirt parameters. Shirt samples are used for fitting assessment and their patterns are measured to investigate the interrelationship between pattern parameters, fitting perceptions and body measurements. The dress shirt samples in terms of its basic shape, fabrication and pattern measurement are described in this section.

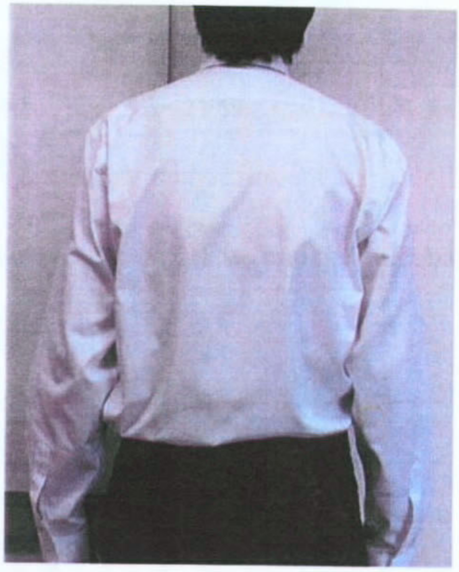
3.5.1 Shirt Samples

Shirt samples with varying degree of fitting for the male subjects are necessary in this study. To minimize the number of shirt samples, one "best-fit" shirt was made for each individual human subject, and the shirt is worn by other human subjects for fitting assessment. An experienced tailor was contracted to make the dress shirts. The tailor alternated the shirt by trials and errors until it perfectly fit the subject.

Fig. 3.39 and 3.40 show the silhouette of the men's dress shirt in front view and back view.

Fig. 3.39 Front View of Dress Shirt

Fig. 3.40 Back View of Dress Shirt



The shirts were made of a 100% white cotton woven fabric, which is a typical fabric men's dress shirt. Moreover, the white colour can better facilitate the visual assessment of appearance and fitting.

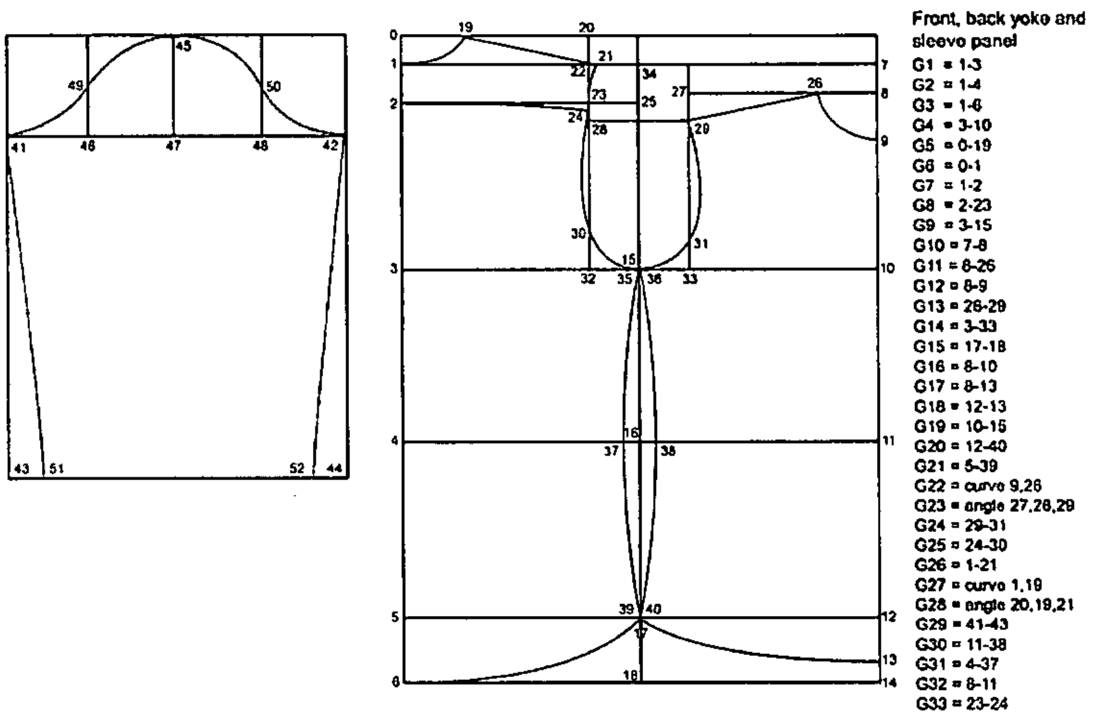
The style of shirt is simple and common. It contains a yoke, long sleeve with cuff, point collar for tie, front placket, and patch pocket in the front.

3.5.2 Men's Shirt Pattern

The shirt pattern consisted of front, back, yoke and sleeve panels. The contracted tailor, based on the body measurements of the subjects, determined the patterns based on his experience.

Fig. 3.41 shows the patterns of front piece, back piece and yoke. Thirty-three pattern parameters (G), G_1 to G_{33}, are considered to be necessary and sufficient for specifying the geometry of the patterns. With these thirty-three pattern parameters, the shirt pattern can be defined and drafted automatically.

Fig. 3.41 Shirt Pattern Parameters



All these shirt pattern parameters are independent and considered as important for pattern drafting. Dependent pattern parameters such as design of upper and lower collar pieces and sleeve width are not specified. The upper and lower collar pieces can be determined by the frontline and back neckline of the shirt pattern. The width of sleeve is determined by armhole measurement of shirt.

3.5.3 Measurement of Pattern Parameters

All pattern pieces excluding the seam allowance from 59 shirts were traced back and were measured manually. These data are essential for establishing the model for the prediction of shirt patterns from body measurements. Each of the 33 pattern parameters was measured by five times, and then the average of the 5 measurements for each parameter was calculated so as to eliminate the error of the manual measurement. The results of pattern measurements are listed in Appendix II.

3.6 Visual Assessments by Tailors and Wearers

The fitting of shirts when worn by different human subjects was visually assessed and rated by tailoring experts and the wearer. Before conducting such subjective rating, the rating procedure and scales were established taking reference to previous research work and advices from a number of designers, tailors, pattern technicians.

3.6.1 Subjective Fitting Assessment

3.6.1.1 Fitting Criteria

According to Coffin (1993), different shapes and postures of body would cause different degree of wrinkling of shirt fabric. The critical areas for men shirt fitting are the areas of shoulder, collar, sleeve and body fit. No matter how loose the shirt, the fitting in such areas is essential for body movement, comfort and visual appearance.

Furthermore, according to ergonomics standards and guidelines for Designers (Pheasant 1987), people are required to bend forward and uplift their arms for work, especially in office environment. Shirts should not be too tight to hinder such movements or too loose to create wrinkled appearance.

Hutchinson et al (1978) stated that the hang of garment from the shoulders is critical to the fit of a garment. Hutchinson believed that a fit garment should be perfectly fit between the neck and the horizontal line around the lower level of the armhole. Stamper et al (1991) stated that the critical areas of garment fit are the neckline, collar and sleeve.

Long sleeve style should have sufficient ease at the elbow to allow the arm to bend comfortably and the sleeve should extend to the wrist bone when the arm is relaxed. The garment should be free of diagonal, vertical or horizontal wrinkles that are not part of the design.

Huck et al (1997) evaluated the subjective fit perception, during which wearers were required to follow the procedure of exercises such as kneel on left knee, duck squat, stand erect etc. The wearers were required to rate the fitting in a 1 to 9 scale, 1 being stiff and 9 being flexible. Similarly, Aldrich et al (1998) required the wearers to perform a series of sitting and standing postures while conducting fitting assessment.

From the past work, it is clear that fitting should assessed at a number of critical areas, such as neckline, shoulder, sleeve length, the front and the back of garment. Furthermore, the wearers should be required to perform a series of activities before rating the fitting perception in a numerical scale.

In this project, five tailors, five designers, five pattern technicians and five researchers were consulted to determine the assessment criteria for men's shirts in terms of the critical fitting areas, fitting requirements and the series of actions the wearers should perform. The experts agreed that the critical areas of shirt fitting are neckline, shoulder point, armhole, front panel, back panel and shirt sleeve. The fitting criteria should include the tightness or looseness perception at these locations both when the wearer is stationary and in movement. When assessing fitting, wearers should be asked to perform a sequence of activities including bending and uplifting their arms, which is in agreement with the requirements specified in the ergonomic standards and guidelines (Pheasant 1987). The experts also suggested that fitting assessment should be carried out by both tailoring experts and the wearer himself.

3.6.2 Assessment Form and Rating Scale

After reviewing the shirt fitting standard and considering the advices from the tailoring experts, an assessment procedure and rating scale were designed (See Table 3.4). Fitting were assessed at the critical areas of shirts in a 1 to 5 scale, 1 being very tight and 5 being very loose when assessing the tightness or looseness or 1 very short and 5 very long when assessing the length.

The assessment form consisted of six sections. The first section is the fitting perception at neck and collar area. Assessors (i.e. the tailoring experts or the wearer himself) were required to rate the fitting when the wearer is standing still and in dynamic movement. The second section was about the fitting of the shoulder point. The third section was about the fitting at the armhole. Assessors were required to assess the fitting when the wearer was in three different statuses, viz. standing still, uplifting both hands (Fig. 3.42) and bending forward of both hands (Fig. 3.43). The fourth section was about the fitting of the front panel of the shirt. The procedure was similar to that of the armhole area. The fifth section was about the fitting of shirt sleeves. The assessors were required to rate the length of sleeves. The last section was about the fitting of back panel. Ratings were given after the wearer performed two actions, viz. uplifting both hands (Fig. 3.42 and 3.44) and bending forward of both hands (Fig. 3.43 and 3.45). An assessment form is shown in Table 3.5.

Fig. 3.42 Uplifting Both Hands

Fig. 3.43 Bending Forward Both Hands

Fig. 3.44 Uplifting Both Hands

Fig. 3.45 Bending Forward Both Hands

Table 3.4 Evaluation Form

1. Collar (with tie)
When standing still

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

When in movement

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

2. Shoulder
2.1 Shoulder point location

Very inadequate	inadequate	Adequate	Loose	Very loose
1	2	3	4	5

3. Armhole
3.1 When standing still

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

3.2 When uplifting two hands

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

3.3 When bending forward

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

4. Posture
4.1 When standing still

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

4.2 When uplifting two hands

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

4.3 When bending forward

Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

5. Sleeve

Too short	Short	Adequate	Long	Too long
1	2	3	4	5

6. Back

6.1 When uplifting two hands				
Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5
6.2 When bending forward				
Very tight	Tight	Adequate	Loose	Very loose
1	2	3	4	5

3.6.3 Process of Subjective Fitting Assessment

Due to time constraints, there is a limit of the number of fitting assessment, which can be carried out. Moreover, it is also meaningless to conduct fitting assessment for extremely unfit shirts for each wearer. Therefore, fitting assessments were conducted for each wearer when wearing 10 different shirt samples including the one, which is tailor-made to best fit him. For example, a wearer had a neck size of 14 inch, he was asked to try on three shirts with neck size ranged from 13inch to 13.5 inch, four shirts with neck size of 14 inch and three shirts with neck size ranged from 14.5 inch to 15 inch. The principle was to ask the wearer to put on shirts with a neck size within 1 inch variation from his neck size.

Wearers may feel tighter at the neckline area when trying on the shirt for the first time, even though the shirts have perfect fit for them. To avoid inappropriate perception, wearers were asked to try on tighter shirts first. After they adapted the tightness feeling of the tight shirt, they were then asked to wear shirts having larger neck size.

3.6.4 Fitting Assessment by the Wearer Himself

The wearer was asked to rate the fitting of the shirt with a tie. After doing a sequence of activities such as putting their hands forward and aside, the wearer was asked to rate the fitting perception using the designed assessment form. They are required to try on 10 different shirts having different neck sizes and shirt sizes.

3.6.5 Fitting Assessment by Experts

Tailors, pattern technicians and designers (evaluation panel) were invited to assess the fitting of the shirts visually, when the wears try on different shirts. The required number of experts in evaluation panel (n) can be determined (Harris 1998 and Aczel 1996) using the following equation (3.1):

$$n = \left(\frac{1.96 * \sigma}{E} \right)^2 \qquad (3.1)$$

where,

n	= number of panel
1.96	= the critical value at level of significance at α=0.05
σ	= standard derivation of each question
E	= maximum allowable error of estimate

From the initial subjective assessment of 20 wearers wearing different shirts and assessed by three panel members including a tailor, a designer and the wearer himself, it was found the maximum standard deviation was 0.55. Assuming the acceptable error of estimate (E) is 0.5, according to the above equation, the number of assessors in the panel (n) should be at least 4.65. Therefore, four experts were invited to rate the fitting.

Together with the wearer, they are altogether five members in the assessment panel. These four panel members included 2 tailors and 2 designers. The results of subjective ratings are listed in Appendix III. The average standard deviation of all subjective ratings was 0.31.

3.7 Conclusions

As discussed in this Chapter, the 59 human subjects invited in the study provide a good representation to the Oriental population except that there may be slightly more slim subjects than the entire population due to the difficulty in recruiting obese subjects in Hong Kong. It was also shown that the Techmath laser scanner used in the investigation has excellent accuracy and provides sufficient body measurement data for further analysis. With the pattern measurement and fitting assessment procedure, shirt pattern can be accurately measured and fitting can be properly assessed for further analysis.

Chapter 4

Comparison and Evaluation of Tailoring Experts' Formulae for Shirt Pattern Drafting

Chapter 4

Comparison and Evaluation of Tailoring Experts' Formulae for Shirt Pattern Drafting

4.1 Introduction

Based on experience, tailoring experts in different countries have their own formulae for calculating the pattern parameters for pattern drafting. These formulae have been available for a period of time, but the appropriateness of such formulae has not been systematically verified so far. Moreover, the formulae developed in western countries may also not be suitable for people in the Eastern countries due to the differences in human anthropometry. Therefore, it is important to evaluate the existing shirt pattern drafting formulae and modify them if necessary.

In evaluating the shirt pattern formulae, body measurements from the 3D laser scanner were used to calculate the pattern parameters using the tailoring formulae. The calculated pattern parameters were then compared with the pattern parameters measured from the fitting shirt of a human subject. The comparison is reported in this Chapter.

4.2 Nomenclature

B_1 - B_{34}	= Body measurements defined in Section 3.2
G_1 - G_{33}	= Pattern parameters defined in Fig. 4.1
Sample Mean	= Summation of actual measurement/no. of samples
Mean error	= (actual measurement – calculated result) / no. of samples
S.D	= Standard deviation
95% confident interval	= mean error – 1.96*SD < e < mean error +1.96*SD
% error in 95% confident interval	= [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD) / mean] *100

4.3 Pattern Drafting Formulae from Four Tailoring Experts

Four shirt pattern drafting techniques and formulae were considered for comparison. These are the Aldrich's method, Cham's method and the methods of two local tailors (Identified as Tailor A and Tailor B). Although the pattern drafting procedures of these four methods are similar, the pattern measurements are determined using different formulae or table conversions from different body measurements and with different ease allowances. Tables 4.4, 4.5 and 4.6 summarize the different pattern drafting formulae used in the four methods for the front, back and yoke panel, respectively. The pattern parameters G_1 to G_{33} are defined according to the illustration shown in Fig. 4.1 and the body measurements B_1 to B_{34} are listed in Table 4.1. The illustration of those thirty-four body measurements is shown at Chapter 3 from Fig. 3.2 to 3.32. Those pattern drafting formulae, which are not so obvious, are explained below.

Fig. 4.1 Shirt Pattern Parameters

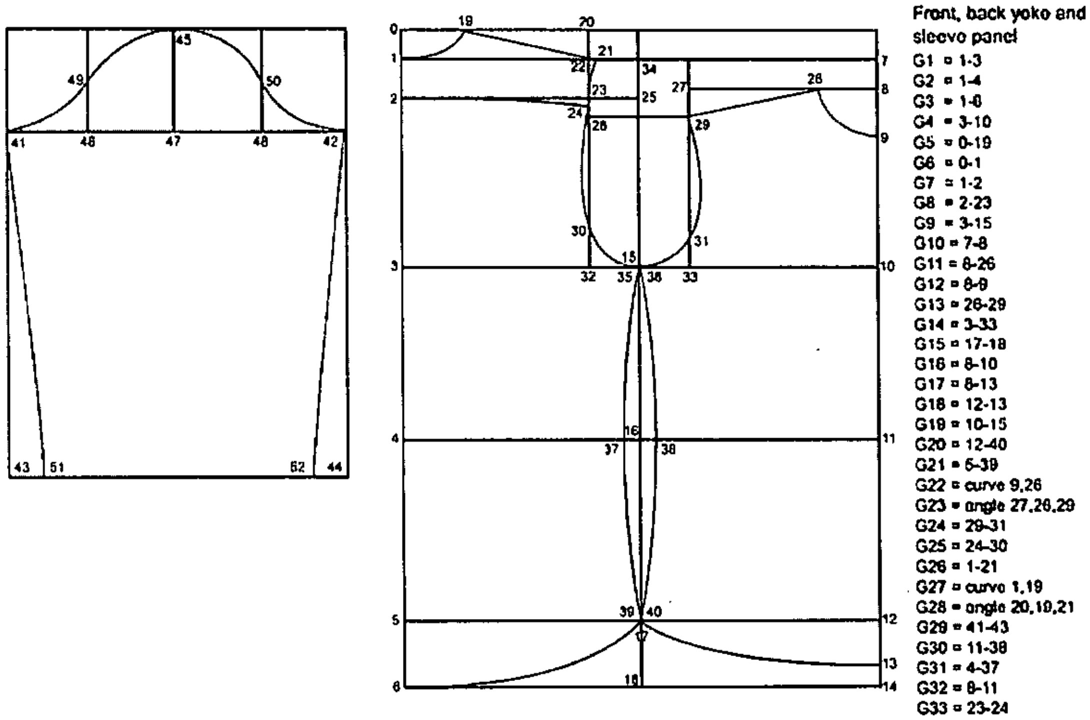


Table 4.1 Body Parameters

Body Parameters	Descriptions	Body Parameters	Descriptions
B_1	Body height	B_{18}	Bust points around neck
B_2	Head height	B_{19}	Bust point to neck
B_3	Distance neck to hip	B_{20}	Chest band
B_4	Neck diameter	B_{21}	Midriff girth
B_5	Mid neck girth	B_{22}	Cross back width
B_6	Side upper torso length	B_{23}	Back width
B_7	Torso width	B_{24}	Neck to underarm back
B_8	Total torso girth	B_{25}	Back length
B_9	Cross shoulder over neck	B_{26}	Back length over shoulder blade
B_{10}	Cross shoulder	B_{27}	Distance armpit-waist
B_{11}	1/2 Shoulder width	B_{28}	Waist to hip back
B_{12}	Shoulder angle L (°)	B_{29}	Waist girth
B_{13}	Shoulder angle R (°)	B_{30}	Waist to hip
B_{14}	Cross front width	B_{31}	Hip girth
B_{15}	Breast width	B_{32}	Arm length to neck back
B_{16}	Neck R to waist over bust	B_{33}	Arm length to neck
B_{17}	Neck front to waist over bust	B_{34}	Arm length

Aldrich determines the front neck depth, G_{12} (8-9), from one-fifth of the neck girth minus 2.5cm, but Cham derives it from one-fourth of neck girth minus 4.5cm, Tailor A obtains the front neck depth using a conversion table (i.e. Table 4.2) and Tailor B calculates it from one fifth of the neck girth minus 4.4. The front neck width G_{11} and front neck line G_{22} are determined similarly.

Table 4.2 Tailor A's conversion table for estimating the front neck depths (G_{12}) front neck width (G_{11}) and back neck width (G_5)

Neck Size (cm)	G_{12} (cm)	G_{11} (cm)	G_5 (cm)
36.8	6.4	7.6	6.7
38.1	6.7	7.6	7.0
39.4	7.0	8.3	7.3
40.6	7.0	8.6	7.3
41.9	7.0	8.6	7.3
43.2	7.3	8.9	7.6
44.5	7.6	9.5	7.9
45.7	7.6	9.8	7.9

In these four methods, the shoulder angle G_{23} and shoulder length G_{13} on the front piece are determined indirectly from other geometrical parameters. In Aldrich's method, G_{23} is determined from the length 26-29 and 27-29, therefore

$$G_{23} = \sin^{-1}\left[\left(\frac{B_{25} - B_{27} + 4}{5} - 1.0\right) / G13\right] \quad (1)$$

G_{13} (or the length 26-29) is determined from the length (19-21) minus 0.5 cm. The length (19-21) is determined from the difference between half back width (1-21) (i.e. $\frac{B_{22}}{2}+4.75$) and neck girth (0-19) (i.e. $\frac{B_5}{5}-0.5$) and the back neck height (4.5 cm) using the principle of Pythagorean Theorem:

$$G_{13}=\sqrt{(\frac{B_{22}}{2}-\frac{B_5}{5}+4.5)^2+(4.5)^2}+0.25 \qquad (2)$$

In Cham's method, G_{23} is determined by determining the length (27-29) and (26-27), therefore

$$G_{23}=\tan^{-1}[(\frac{B_5}{8}-1)/\frac{B_{20}}{4}+0.5] \qquad (3)$$

and G_{13} is determined from the length of a quarter of the chest girth and 1/8 of neck girth and the 1/8 of neck girth:

$$G_{13}=\sqrt{(\frac{B_{20}}{4}-\frac{B_5}{8}-1.75)^2+(\frac{B_5}{8}-1)^2} \qquad (4)$$

In Tailor A's method, G_{23} is also determined from the length (27-29) and (26-27), hence

$$G_{23} = \tan^{-1}[(6.4)/\frac{B_{10}}{2}] \qquad (5)$$

and G_{13} is determined from the half of the cross shoulder length and the front neck depth:

$$G_{13} = \sqrt{(\frac{B_{10}}{2})^2 + (6.4)^2} \qquad (6)$$

In Tailor B's method, G_{23} is determined from the length (27-29) and (26-27), hence

$$G_{23} = \sin^{-1}[3.9 \cdot \cos 14.0^{o} /(\frac{B_{10}}{2})] \qquad (7)$$

G_{13} is determined from the half cross shoulder length and the shoulder angle on the front panel:

$$G_{13} = (\frac{B_{10}}{2})/\cos 14.0^{\circ} \qquad (8)$$

G_{18} is a parameter related to the style of hemline. It can be varied depending on customers' requirement. Aldrich assumed it to be 16 cm, whereas Tailor A and B set it to be 6.5 cm. As for Cham's method, G_{18} is derived from the length (1-6) minus the length (1-3), (3-4), (4-5) and (13-14). In this method, the length (1-6) is estimated from the required shirt length plus 4 cm, the sum of the length (1-3) and (3-4) is estimated from the natural waist length plus 4.5 cm, the length (4-5) is calculated from one eighth of the body height plus 2.5 cm and the length (13-14) is assumed to be 5.0 cm, we therefore have:

$$G_{18} = SL - B_{25} - \frac{B_1}{8} - 8 \quad (9)$$

In all four methods, G_{19} are determined from one fourth of the chest girth plus different ease allowances.

In Aldrich's method, G_{16} is the body scye depth minus 4.5 cm. In cham's method, G_{16} is the sum of the front neck depth (i.e. G_{12}) and the length (9-10), which is one fourth of the chest girth minus 6 cm. In Tailor A's method, G_{16} is the scye depth estimated using the conversion Table 4.3 minus 2.5 inches (or 6.4 cm). In Tailor B's method, G_{16} is one fourth of the chest girth minus 4.1 cm.

Table 4.3 Tailor A's Conversion Table for Estimating Scye Depth

Chest girth (cm)	Scye Depth (cm)
101.6	18.4
106.7	18.4
111.8	19.1
116.8	19.7
116.8 + n*5.1	19.7+ n*1.3

Note: n is an integer

The shoulder angle on the yoke, G_{28}, is calculated from the length (19-20) and (20-22) in Aldrich's, Cham's and Tailor A's method, which are determined from different body measurements. In Aldrich's method,

$$G_{28} = \tan^{-1}\left[\frac{4.5}{\frac{B_{22}}{2} - \frac{B_5}{5} + 4.5}\right] \quad (10)$$

In Cham's method,

$$G_{28} = \tan^{-1}\left[\frac{\frac{B_5}{8} - 1}{\frac{B_{20}}{4} - \frac{B_5}{8} - 2.8}\right] \quad (11)$$

In Tailor A's method,

$$G_{28} = \tan^{-1}\left[\frac{3.2}{\frac{B_{22}}{2} + 5.1 - G5}\right] \quad (12)$$

Tailor B fixes G_{28} to 14.0° for all shirts.

G_{22} and G_{27} are determined from drawing respective free hand curves. And others parameters are determined by style.

Table 4.4 The Formulae of 4 Tailoring Experts on Front Shirt Panel

Front Parameter	*Aldrich*	*Cham*	*Tailor A*	*Tailor B*
G_{10}	4.5	$14-\frac{B_5}{4}$	5.1	4.1
G_{11}	$\frac{B_5}{5}-1$	$\frac{B_5}{8}+2.25$	See Table 4.2	$\frac{B_5}{5}-3.2$
G_{12}	$\frac{B_5}{5}-2.5$	$\frac{B_5}{4}-4.5$	See Table 4.2	$\frac{B_5}{5}-4.4$
G_{13}	Equation (2)	Equation (4)	Equation (6)	Equation (8)
G_{16}	$B_{25}-B_{27}-0.5$	$\frac{B_{20}}{4}-6$	See Table 4.3	$\frac{B_{20}}{4}-4.1$
G_{17}	$SL-0.5$	$SL-B_{25}-\frac{B_1}{8}-3$	$SL-7.6$	$SL-4.1$
G_{18}	16	Equation (9)	6.5	6.5
G_{19}	$\frac{B_{20}}{2}-\frac{B_{20}}{4}+5.5$	$\frac{B_{20}}{4}+4$	$\frac{B_{20}}{4}+1.9$	$\frac{B_{20}}{4}$
G_{20}	$\frac{B_{20}}{2}-\frac{B_{20}}{4}+4.5$	$\frac{B_{20}}{4}+4$	$\frac{B_{31}}{4}+6.4$	$\frac{B_{20}}{4}$
G_{21}	From Drawing curve 9,26	From Drawing curve 9,26	From Drawing curve 9,26	From Drawing curve 9,26
G_{23}	Equation (1)	Equation (3)	Equation (5)	Equation (7)
G_{30}	$\frac{B_{20}}{2}-\frac{B_{20}}{4}+3.5$	$\frac{B_{20}}{4}+2.5$	$\frac{B_{20}}{4}+3.9$	$\frac{B_{20}}{4}-2$
G_{32}	$B_{25}-0.5$	$B_{25}+\frac{B_5}{4}-9.5$	B_{25}	$B_{25}-4.1$

Table 4.5 The Formulae of 4 Tailoring Experts on Back Shirt Panel

Back Parameter	*Aldrich*	*Cham*	*Tailor A*	*Tailor B*
G_1	$B_{25} - B_{27} + 4$	$\frac{B_{20}}{4} + 3.5$	$\frac{B_{20}}{4} + 2.5$	$\frac{B_{20}}{4}$
G_2	$B_{25} + 3$	$B_{25} + 4.5$	B_{25}	B_{25}
G_3	$SL + 8$	$SL + 4$	$SL + 2.5$	SL
G_4	$\frac{B_{20}}{2} + 12$	$\frac{B_{20}}{2} + 8$	$B_{25} + \frac{B_{20}}{4} + 2.5$	$\frac{B_{20}}{2}$
G_9	$\frac{B_{20}}{4} + 6.5$	$\frac{B_{20}}{4} + 4$	$\frac{B_{20}}{4} + 6.4$	$\frac{B_{20}}{4}$
G_{15}	20	$SL - B_{25} - \frac{B_1}{8} - 3$	6.4	6.5
G_{21}	$\frac{B_{20}}{4} + 5.5$	$\frac{B_{20}}{4} + 4$	$\frac{B_{31}}{4} + 6.4$	$\frac{B_{20}}{4}$
G_{31}	$\frac{B_{20}}{4} + 4.5$	$\frac{B_{20}}{4} + 2.5$	$\frac{B_{20}}{4} + 3.9$	$\frac{B_{20}}{4} - 2$
G_{33}	0.75	1	1.3	1

Table 4.6 The Formulae of 4 Tailoring Experts on Yoke Shirt Panel

Yoke and Sleeve Parameter	*Aldrich*	*Cham*	*Tailor A*	*Tailor B*
G_5	$\frac{B_5}{5}-0.5$	$\frac{B_5}{8}+2.25$	See Table 4.2	$\frac{B_5}{5}+1.2$
G_6	4.5	$\frac{B_5}{8}-1$	5.1	6
G_7	$\frac{(B_{25}-B_{27}+4)}{5}+2$	$\frac{B_{20}}{16}+3$	8.9	8
G_8	$\frac{B_{22}}{2}+4$	$\frac{B_{20}}{4}-1.5$	$\frac{B_{22}}{2}+5.1$	$\frac{B_{10}}{2}$
G_{26}	$\frac{B_{22}}{2}+4.75$	$\frac{B_{20}}{4}-0.5$	$\frac{B_{10}}{2}+G5$	$\frac{B_{10}}{2}+0.7$
G_{27}	From Drawing curve 1,19	From Drawing curve 1,19	From Drawing curve 1,19	From Drawing curve 1,19
G_{28}	Equation (10)	Equation (11)	Equation (12)	14°
G_{29}	$B_{34}+6$	$B_{34}+6$	B_{34}	B_{34}

4.4 The Appropriateness of the Existing Pattern Drafting Formulae

The shirt patterns of the best-fit shirts of 59 subjects were manually measured and compared with the calculated pattern parameters using the four tailoring experts' formulae. The required body parameters were input into the formulae or conversion table for calculating the shirt pattern parameters for the 59 human subjects. Tables 4.7 to 4.10 present the deviation of the calculated pattern parameters, from the pattern measurements of the best-fit shirts as well as their correlation (R^2).

In these tables, "Sample Mean" is the average of the pattern measurements of the 59 best-fit shirts. The "Mean Error" is the average of the deviation of the calculated pattern parameters from the measured pattern parameters from the 59 best-fit shirts. The "SD" is the standard deviation of the deviation. The "95% confidence interval" in centimeter is a measure of the range of deviation in length and the "%error in 95% confidence interval" is a measure of the range of deviation in percent. The last column in the tables list the correlation (R^2) between shirt pattern parameters actually measured from the 59 best-fit shirts and those calculated using the tailoring experts' formulae or conversion table. The detailed calculation equations are described in the footnotes of Table 4.7 to Table 4.10.

4.4.1 Evaluation of Aldrich's Formulae

The data in table 4.7 are the deviations and correlations (R^2) of Aldrich's formulae. The highest correlation (R^2) is around 0.8, these pattern parameters are G_4 (3-10), G_9 (3-15) and G_{19} (10-15). They are the half chest girth, back chest girth and front chest girth respectively. For G_4, the mean error is –1.81 cm; the standard deviation is 2.04 cm and the maximum deviation based on 95% confidence limit can be 10.61%. For G9, the mean error is –1.45 cm; the standard deviation is 0.99 cm and the maximum deviation based on 95% confidence limit can be 12.41%. For G_{19}, the mean error is –0.40 cm; the standard deviation is 0.97 cm and the maximum deviation based on 95% confidence limit can be 8.42%.

The second high correlation (R^2) is around 0.60, those parameters are the G_{11} (8-26), G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the front neck width, front hip girth, back hip girth, front waist girth and back waist girth respectively. For G_{11}, the mean error is –0.12 cm; the standard deviation is 0.28 cm and the maximum deviation based on 95% confidence limit can be 11.09%. For G_{20}, the mean error is 0.55 cm; the standard deviation is 1.25 cm and the maximum deviation based on 95% confidence limit can be 11.00%. For G_{21}, the mean error is –0.54 cm; the standard deviation is 1.26 cm and the maximum deviation based on 95% confidence limit can be 11.05%. For G_{30}, the mean error is –1.30 cm; the standard deviation is 1.53 cm and the maximum deviation based on 95% confidence limit can be 17.49%. For G_{31}, the mean error is –2.35 cm; the standard deviation is 1.52 cm and the maximum deviation based on 95% confidence limit can be 21.79%.

The maximum deviation based on 95% confident limit of other pattern parameters is relatively high. Moreover, the correlation between the pattern measurements of the best-fit shirts and those calculated from the formulae is low. It implies that the pattern formulae from Aldrich are not appropriate in shirt pattern drafting for Oriental people.

Table 4.7 Deviation of Aldrich's Formulae and Correlation (R^2) between Pattern Measurements of Best Fit shirts and Those Calculated from Aldrich's formulae

Pattern Parameters	Deviation of Aldrich's Formulae					Correlation (R^2)
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)	
G_1	29.21	1.44	6.68	3.87~9.49	13.24~32.50	0.15
G_2	47.63	4.52	3.64	-5.22~12.49	-10.96~26.23	0.01
G_4	54.78	2.04	-1.81	-5.81~2.18	-10.61~3.98	0.79
G_5	8.36	0.43	1.62	0.78~2.46	9.31~29.41	0.25
G_6	5.37	0.32	0.87	0.25~1.49	4.70~27.74	0.00
G_7	7.58	0.65	1.07	-0.20~2.35	-2.64~30.98	0.03
G_8	23.31	0.96	1.31	-0.57~3.18	-2.43~13.65	0.38
G_9	27.35	0.99	-1.45	-3.39~0.50	-12.41~1.81	0.80
G_{10}	5.73	1.52	1.23	-1.74~4.20	-30.39~73.32	0.00
G_{11}	6.12	0.28	-0.12	-0.68~0.43	-11.09~7.01	0.64
G_{12}	5.18	0.64	-1.04	-2.29~0.21	-44.13~4.13	0.29
G_{13}	16.37	0.98	0.21	-1.71~2.13	-10.46~12.98	0.23
G_{16}	23.40	1.76	5.37	1.92~8.83	8.21~37.72	0.02
G_{19}	27.40	0.97	-0.40	-2.31~1.51	-8.42~5.52	0.81
G_{20}	27.35	1.25	0.55	-1.91~3.01	-6.98~11.00	0.68
G_{21}	27.26	1.26	-0.54	-3.01~1.93	-11.05~7.08	0.68
G_{23}	20.91	1.76	8.34	4.90~11.78	23.44~56.37	0.02
G_{26}	24.46	0.95	1.70	-0.15~3.56	-0.63~14.55	0.40
G_{28}	12.49	1.54	-4.01	-7.02~-1.00	-56.21~-8.01	0.01
G_{29}	43.70	2.08	-23.52	-27.59~-19.45	-63.12~-44.50	0.59
G_{30}	24.50	1.53	-1.30	-4.29~1.70	-17.49~6.92	0.61
G_{31}	24.45	1.52	-2.35	-5.33~0.64	-21.79~2.60	0.62
G_{32}	42.93	3.87	2.44	-5.15~10.03	-12.00~23.36	0.13
G_{33}	2.41	0.71	1.66	0.27~3.04	11.20~126.48	0.00

Note:
a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error + 1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

4.4.2 Evaluation of Cham's Formulae

Table 4.8 shows the deviations and correlation (R^2) of Cham's formulae. The highest correlation (R^2) is around 0.8, those pattern parameters are the G_4 (3-10), G_9 (3-15) and G_{19} (10-15). They are the half chest girth, back chest girth and front chest girth respectively. For G_4, the mean error is 2.19 cm; the standard deviation is 2.04 cm and the maximum deviation based on 95% confidence limit can be 11.29%. For G9, the mean error is 1.05 cm; the standard deviation is 0.99 cm and the maximum deviation based on 95% confidence limit can be 10.95%. For G_{19}, the mean error is 1.10 cm; the standard deviation is 0.97 cm and the maximum deviation based on 95% confidence limit can be 10.99%.

The second high correlation (R^2) is around 0.60, those parameters are the G_{11} (8-26), G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the front neck width, front hip girth, back hip girth, front waist girth and back waist girth respectively. For G_{11}, the mean error is –0.66 cm; the standard deviation is 0.29 cm and the maximum deviation based on 95% confidence limit can be 19.94%. For G_{20}, the mean error is 1.05 cm; the standard deviation is 1.25 cm and the maximum deviation based on 95% confidence limit can be 12.82%. For G_{21}, the mean error is 0.96 cm; the standard deviation is 1.26 cm and the maximum deviation based on 95% confidence limit can be 12.59%. For G_{30}, the mean error is –0.30 cm; the standard deviation is 1.53 cm and the maximum deviation based on 95% confidence limit can be 13.41%. For G_{31}, the mean error is –0.35 cm; the standard deviation is 1.52 cm and the maximum deviation based on 95% confidence limit can be 13.61%.

The correlation and maximum deviation based on 95% of other pattern parameters are very poor. Although Cham is from an Oriental country, the calculated pattern parameters can still not produce fitting shirts for the human subjects in the investigation. It may imply that the anthropometrical data used was obsolesced.

Table 4.8 Deviation of Cham's Formulae and Correlation (R^2) between Pattern Measurements of Best Fit shirts and Those Calculated from Cham's formulae

Pattern Parameters	Deviation of Cham's Formulae					Correlation la (R^2)
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)	
G_1	29.21	2.24	3.41	-0.98~7.80	-3.36~26.72	0.07
G_2	47.63	4.52	2.14	-6.72~10.99	-14.11~23.08	0.01
G_4	54.78	2.04	2.19	-1.81~6.18	-3.31~11.29	0.79
G_5	8.36	0.37	1.59	0.86~2.31	10.33~27.60	0.25
G_6	5.37	0.44	1.84	0.99~2.70	18.34~50.28	0.00
G_7	7.58	0.94	-1.00	-2.83~0.84	-37.33~11.07	0.05
G_8	23.31	1.84	2.51	-1.10~6.13	-4.73~26.29	0.32
G_9	27.35	0.99	1.05	-0.89~3.00	-3.27~10.95	0.80
G_{10}	5.73	1.51	0.79	-2.17~3.74	-37.82~65.25	0.04
G_{11}	6.12	0.29	-0.66	-1.22~-0.10	-19.94~-1.55	0.64
G_{12}	5.18	0.70	-1.56	-2.93~-0.18	-56.55~-3.51	0.15
G_{13}	16.37	2.00	-0.04	-3.96~3.88	-24.21~23.72	0.05
G_{16}	23.40	1.89	7.10	3.40~10.80	14.55~46.16	0.28
G_{19}	27.40	0.97	1.10	-0.81~3.01	-2.94~10.99	0.81
G_{20}	27.35	1.25	1.05	-1.41~3.51	-5.15~12.82	0.68
G_{21}	27.26	1.26	0.96	-1.51~3.43	-5.55~12.59	0.68
G_{23}	20.91	1.49	12.08	9.17~14.99	43.85~71.71	0.08
G_{26}	24.46	1.99	2.66	-1.23~6.55	-5.05~26.78	0.19
G_{28}	12.49	1.58	-0.89	-3.98~2.20	-31.87~17.58	0.02
G_{29}	43.70	2.08	-23.52	-27.59~-19.45	-63.12~-44.50	0.59
G_{30}	24.50	1.53	-0.30	-3.29~2.70	-13.41~11.00	0.61
G_{31}	24.45	1.52	-0.35	-3.33~2.64	-13.61~10.78	0.62
G_{32}	42.93	3.86	2.38	-5.18~9.95	-12.07~23.17	0.16
G_{33}	2.41	0.71	1.41	0.02~2.79	0.81~116.09	0.00

Note:

a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error +1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

4.4.3 Evaluation of Tailor A's Formulae or Conversion Table

Table 4.9 shows the deviations and correlation (R^2) of Tailor A's formulae or conversion table. The highest correlation (R^2) is around 0.8, those pattern parameters are G_9 (3-15) and G_{19} (10-15). They are the back chest girth and front chest girth respectively. For G_9, the mean error is −1.35 cm; the standard deviation is 0.99 cm and the maximum deviation based on 95% confidence limit can be 12.05%. For G_{19}, the mean error is 3.20 cm; the standard deviation is 0.97 cm and the maximum deviation based on 95% confidence limit can be 18.66%.

The second high correlation (R^2) is larger than 0.60, those parameters are the G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the front hip girth, back hip girth, front waist girth and back waist girth respectively. For G_{20}, the mean error is −2.18 cm; the standard deviation is 0.98 cm and the maximum deviation based on 95% confidence limit can be 14.99%. For G_{21}, the mean error is −2.27 cm; the standard deviation is 1.03 cm and the maximum deviation based on 95% confidence limit can be 15.76%. For G_{30}, the mean error is −1.70 cm; the standard deviation is 1.53 cm and the maximum deviation based on 95% confidence limit can be 19.13%. For G_{31}, the mean error is −1.75 cm; the standard deviation is 1.52 cm and the maximum deviation based on 95% confidence limit can be 19.33%.

Table 4.9 Deviation of Tailor A's Formulae and Correlation (R^2) between Pattern Measurements of Best Fit shirts and Those Calculated from Tailor A's formulae

Pattern Parameters	Deviation of Tailor A's Formulae					Correlation (R^2)
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)	
G_1	29.21	2.24	4.41	0.02~8.80	0.06~30.14	0.07
G_2	47.63	4.52	6.64	-2.22~15.49	-4.66~32.53	0.01
G_4	54.78	4.36	-11.01	-19.54~-2.47	-35.68~-4.51	0.22
G_5	8.36	0.39	1.53	0.76~2.30	9.03~27.49	0.17
G_6	5.37	0.32	0.27	-0.35~0.89	-6.47~16.57	0.00
G_7	7.58	0.64	-1.32	-2.57~-0.07	-33.95~-0.89	0.00
G_8	23.31	0.96	0.21	-1.67~2.08	-7.15~8.93	0.38
G_9	27.35	0.99	-1.35	-3.29~0.60	-12.05~2.18	0.80
G_{10}	5.73	1.52	0.63	-2.34~3.60	-40.87~62.85	0.00
G_{11}	6.12	0.33	-1.63	-2.27~-0.99	-37.02~-16.15	0.50
G_{12}	5.18	0.66	-1.35	-2.65~-0.06	-51.08~-1.18	0.25
G_{13}	16.37	1.43	-5.63	-8.44~-2.82	-51.58~-17.23	0.17
G_{16}	23.40	1.33	4.97	2.37~7.57	10.11~32.35	0.06
G_{19}	27.40	0.97	3.20	1.29~5.11	4.72~18.66	0.81
G_{20}	27.35	0.98	-2.18	-4.10~-0.26	-14.99~-0.95	0.74
G_{21}	27.26	1.03	-2.27	-4.30~-0.24	-15.76~-0.88	0.70
G_{23}	20.91	1.77	3.90	0.42~7.38	2.03~35.29	0.05
G_{26}	24.46	1.39	-3.42	-6.15~-0.70	-25.14~-2.85	0.37
G_{28}	12.49	1.27	1.31	-1.17~3.79	-9.33~30.37	0.04
G_{29}	43.70	2.08	-17.52	-21.59~-13.45	-49.39~-30.77	0.59
G_{30}	24.50	1.53	-1.70	-4.69~1.30	-19.13~5.29	0.61
G_{31}	24.45	1.52	-1.75	-4.73~1.24	-19.33~5.06	0.62
G_{32}	42.93	3.87	1.94	-5.65~9.53	-13.16~22.20	0.13
G_{33}	2.41	0.71	1.11	-0.28~2.49	-11.66~103.63	0.00

Note:
a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error +1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

4.4.4 Evaluation of Tailor B's Formulae

Table 4.10 shows the deviations and correlation (R^2) of Tailor B's formulae. The highest correlation (R^2) is around 0.8, those pattern parameters are G_4 (3-10), G_9 (3-15) and G_{19} (10-15). They are the half chest girth, back chest girth and front chest girth respectively. For G_4, the mean error is 10.19 cm; the standard deviation is 2.04 cm and the maximum deviation based on 95% confidence limit can be 25.89%. For G_9, the mean error is 5.05 cm; the standard deviation is 0.99 cm and the maximum deviation based on 95% confidence limit can be 25.58%. For G_{19}, the mean error is 5.10 cm; the standard deviation is 0.97 cm and the maximum deviation based on 95% confidence limit can be 25.59%.

The second high correlation (R^2) is around 0.60, those parameters are the G_{11} (8-26), G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the front neck width, front hip girth, back hip girth, front waist girth and back waist girth respectively. For G_{11}, the mean error is 2.08 cm; the standard deviation is 0.28 cm and the maximum deviation based on 95% confidence limit can be 42.96%. For G_{20}, the mean error is 5.05 cm; the standard deviation is 1.25 cm and the maximum deviation based on 95% confidence limit can be 27.45%. For G_{21}, the mean error is 4.96 cm; the standard deviation is 1.26 cm and the maximum deviation based on 95% confidence limit can be 27.26%. For G_{30}, the mean error is 4.20 cm; the standard deviation is 1.53 cm and the maximum deviation based on 95% confidence limit can be 29.37%. For G_{31}, the mean error is 4.15 cm; the standard deviation is 1.52 cm and the maximum deviation based on 95% confidence limit can be 29.19%.

Table 4.10 Deviation of Tailor B's Formulae and Correlation (R^2) between Pattern Measurements of Best Fit shirts and Those Calculated from Tailor B's formulae

Pattern Parameters	Deviation of Tailor B's Formulae					Correlation between Actual shirt pattern measurements and calculated results from author's formula (R^2)
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)	
G_1	29.21	2.24	6.91	2.52~11.30	8.62~38.70	0.07
G_2	47.63	4.52	6.64	-2.22~15.49	-4.66~32.53	0.01
G_4	54.78	2.04	10.19	6.19~14.18	11.30~25.89	0.79
G_5	8.36	0.43	-0.08	-0.92~0.76	-11.01~9.08	0.25
G_6	5.37	0.32	-0.63	-1.25~-0.01	-23.23~-0.19	0.00
G_7	7.58	0.64	-0.42	-1.67~0.83	-22.07~10.98	0.00
G_8	23.31	1.41	2.27	-0.49~5.03	-2.11~21.58	0.26
G_9	27.35	0.99	5.05	3.11~7.00	11.35~25.58	0.80
G_{10}	5.73	1.52	1.63	-1.34~4.60	-23.41~80.30	0.00
G_{11}	6.12	0.28	2.08	1.52~2.63	24.85~42.96	0.64
G_{12}	5.18	0.63	1.16	-0.07~2.38	-1.31~46.00	0.31
G_{13}	16.37	1.54	-5.32	-8.34~-2.30	-50.92~-14.06	0.17
G_{16}	23.40	1.89	5.20	1.50~8.90	6.43~38.04	0.28
G_{19}	27.40	0.97	5.10	3.19~7.01	11.66~25.59	0.81
G_{20}	27.35	1.25	5.05	2.59~7.51	9.47~27.45	0.68
G_{21}	27.26	1.26	4.96	2.49~7.43	9.13~27.26	0.68
G_{23}	20.91	1.59	10.48	7.37~13.60	35.23~65.04	0.05
G_{26}	24.46	1.30	2.71	0.17~5.26	0.68~21.52	0.36
G_{28}	12.49	1.19	-1.51	-3.84~0.82	-30.70~6.55	0.00
G_{29}	43.70	2.08	-17.52	-21.59~-13.45	-49.39~-30.77	0.59
G_{30}	24.50	1.53	4.20	1.21~7.20	4.95~29.37	0.61
G_{31}	24.45	1.52	4.15	1.17~7.14	4.79~29.19	0.62
G_{32}	42.93	3.87	6.04	-1.55~13.63	-3.61~31.75	0.13
G_{33}	2.41	0.71	1.41	0.02~2.79	0.81~116.09	0.00

Note: a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error +1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

4.5 Conclusion

In general, the calculated pattern parameters using experts' formulae have very high deviations from the pattern measurements of the best-fit shirts. Before concluding that the experts' formulae for pattern making do not provide proper fit to the diverse body shape, one may argue that the body measurements from the Techmath scanner may be different from those of the manual measurements by the tailors, which might cause the high deviation.

If the high deviation of the calculated parameters from the actual shirt measurements was mainly caused by the differences between the body measurements from the Techmath body scanner and those from tailor's manual measurements, the calculated pattern parameters should at least have a high correlation with the pattern measurements of the best-fit shirts, since manual body measurements must be highly related to the body measurements from the scanner. To examine this, correlation between the measured pattern parameters from the best-fit shirts and the calculated ones using the existing formulae was analyzed and the results are listed on the right columns of Tables 4.7 to 4.10.

Furthermore, manual body measurements have been compared with the body measurements from Tecmach body scanner (See Table 3.1). There are no significant differences between the manual and scanner measurements, especially for those required by the tailoring experts, such as neck girth, chest girth, waist girth, hip girth and sleeve length. Therefore, the assumption, that the high deviation of the tailoring experts' formulae is a result of the differences between the manual and scanner body measurements, is not valid.

As can been seen from the above tables, none of the four experts' formulae showed any significant advantage in terms of the correlation. Even the pattern drafting formulae from the tailor A, who made the best-fit shirts, were not any better. This is because considerable pattern alteration and adjustments have been made by the contracted tailor to make the shirts fit to each of the 59 human subjects.

Better correlations between the calculated pattern parameters from the experts' formulae and measured pattern parameters from the best-fit shirts are found among the horizontal measurements such as chest girth, waist girth and hip girth. It may be due to the fact that these traditional shirt pattern-drafting methods are mainly based on the linear relationship with body measurements. The relative high squared correlation (R^2) obtained from these pattern parameters indicate that the horizontal pattern parameters have approximately linear relationship with corresponding body measurements. However, the maximum deviations based on the 95% confident interval of all pattern parameters are still too high. That means the prediction error from those formulae is too high.

It could be concluded that the tailoring formulae are not accurate enough. Although three of the four tailoring experts are local, their formulae cannot directly produce fitting shirts patterns for the target consumer. One possible reason is that human anthropometry changes with time. Old formulae may not be appropriate for the present time. Furthermore, the co-existence of different versions of pattern drafting formulae is another indication of the limitations of each of the formulae.

To conclude, the results demonstrated that the patterns drafted using the four tailoring experts' methods could not provide adequate fit to customers of diverse body shape. Improved pattern drafting formulae are required for individual fit, which is essential to the implementation of the much desired mass customization. It is believed that the relationship between pattern parameters and body parameter is not just correlated with one single body parameter. Therefore, pattern-drafting formulae based on the multiple linear regression should be established, which is to be reported in next Chapter.

Chapter 5

Prediction of Men's Shirt Pattern by Multiple Linear Regression

Chapter 5

Prediction of Men's Shirt Pattern by Multiple Linear Regression

5.1 Introduction

As discussed in Chapter 4, existing pattern drafting formulae are inappropriate in calculating the pattern parameters to achieve individual fit. In the present practice, trial and error are the norm to achieve desirable fit for target consumer, which is clearly inadequate for the implementation of mass customization. Consequently, it is important to improve the prediction accuracy of the pattern drafting formulae.

To establish better pattern drafting formulae, the first step is to understand the interrelationship between pattern parameters and body measurements. One possible reason for the deficiency of the existing pattern drafting formulae are that one pattern parameter is only predicted from one single body measurement. However, the reality is that one pattern parameter may be related to two or more body measurements. To consider the multiple correlation in this Chapter, the pattern parameters of best-fit shirts are correlated with the body measurements by applying the multiple linear regression.

5.2 Nomenclature

y	= Dependent variable (Pattern parameters) or value of dependent variable
β_0	= Constant or intercept
$\beta_{1..}\beta_p$	= Coefficients or slope
$x_{1...}x_p$	= Independent variable (Body parameters)
ε	= Errors (the vertical difference between predicted value and actual value)
B_1 - B_{34}	= Body measurements defined in Section 3.2
G_1 - G_{33}	= Pattern parameters defined in Fig. 5.1
Sample Mean	= Summation of actual measurement/no. of samples
Mean error	= (actual measurement – calculated result) / no. of samples
S.D	= Standard deviation
95% confident interval	= mean error – 1.96*SD < e < mean error +1.96*SD
% error in 95% confident interval	= [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD) / mean] *100

5.3 Multiple Linear Regression (MLR)

Multiple Linear Regression is a statistical method for predicting a dependant variable from a number of independent variables, assuming linear relationship exists between the dependent variable and any of the independent variables. The aim of Multiple Linear Regression is to establish the following relationship:

$$y = \beta_0 + \beta_1 x_1 + ... + \beta_p x_p + \varepsilon \qquad (5.1)$$

where,

y = Dependent variable (Pattern parameters)

β_0 = Constant or intercept

$\beta_{1..}\beta_p$ = Coefficients or slope

$x_{1...}x_p$ = Independent variable (Body parameters)

ε = Errors (the vertical difference between predicted value and actual value)

Moreover, in order to identify important independent variables (body parameters), which can significantly contribute model prediction, stepwise variable selection was applied.

This variable selection method is a combination of features of backward and forward methods. Firstly, the variable with the largest positive or negative correlation with the dependent variable was considered for entry into the equation. In the example as shown in Table 5.1, body parameter B_6 was the first variable for entry into the model. In the next step, variables not in the equation were examined for entry. The criterion for entry was that either the F value was greater than a threshold value or the partial correlation was the highest one. In Table 5.1, the variable B_8 has the highest partial correlation, and hence this variable was added into the model. After this, each of the variables existed in the model would be evaluated for removal. The criterion for removal was that the F value of the model was less than a threshold value if the variable is removed. If there were no variables eligible for removal, the remaining variables would be considered for entry into the equation again when it met the requirement for selection. If one independent variable was removed, other variables would be considered for entry into the equation. Those procedures would be performed iteratively until there was no more independent variables for entry into the equation then the variable selection would be terminated. As can be seen from Table 5.1, model 2 has no additional independent variable to be entered after selecting the variables B_6. Stepwise variable selection method ensures highly correlated variables to be selected into the model and avoids the highly correlated independent variables co-existed in the model (Norusis 1988).

Table 5.1 Example of Variable Selection in Multiple Linear Regression Model

Excluded Variables[c]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics		
						Tolerance	VIF	Minimum Tolerance
1	B1	.185[a]	1.546	.128	.202	.965	1.037	.965
	B2	-.043[a]	-.339	.736	-.045	.882	1.134	.882
	B3	.308[a]	2.563	.013	.324	.890	1.123	.890
	B8	.411[a]	3.521	.001	.426	.859	1.164	.859
	B16	.142[a]	.853	.397	.113	.514	1.947	.514
	B17	-.078[a]	-.429	.670	-.057	.429	2.332	.429
	B18	.271[a]	2.316	.024	.296	.956	1.046	.956
	B19	.182[a]	1.504	.138	.197	.941	1.063	.941
	B24	.260[a]	2.264	.027	.290	.999	1.001	.999
	B25	.139[a]	.717	.476	.095	.377	2.651	.377
	B26	.272[a]	1.436	.157	.188	.385	2.600	.385
	B27	-.176[a]	-.842	.403	-.112	.325	3.079	.325
	B28	.236[a]	1.559	.125	.204	.601	1.664	.601
	B30	.192[a]	1.605	.114	.210	.962	1.039	.962
	B32	.367[a]	3.332	.002	.407	.983	1.017	.983
	B33	.336[a]	2.955	.005	.367	.957	1.045	.957
	B34	.155[a]	1.315	.194	.173	.999	1.001	.999
2	B1	-.033[b]	-.249	.804	-.034	.688	1.454	.613
	B2	-.189[b]	-1.576	.121	-.208	.796	1.257	.775
	B3	.085[b]	.568	.572	.076	.530	1.885	.512
	B16	-.061[b]	-.371	.712	-.050	.445	2.246	.445
	B17	-.234[b]	-1.384	.172	-.184	.403	2.480	.403
	B18	.089[b]	.674	.503	.091	.686	1.458	.616
	B19	.025[b]	.206	.838	.028	.784	1.276	.715
	B24	.153[b]	1.349	.183	.179	.897	1.115	.771
	B25	-.050[b]	-.270	.788	-.036	.344	2.909	.344
	B26	.052[b]	.273	.786	.037	.332	3.011	.332
	B27	-.233[b]	-1.227	.225	-.163	.323	3.101	.316
	B28	.075[b]	.499	.620	.067	.529	1.889	.455
	B30	.080[b]	.685	.496	.092	.872	1.147	.778
	B32	.234[b]	1.904	.062	.249	.740	1.351	.647
	B33	.214[b]	1.800	.077	.236	.801	1.248	.719
	B34	.036[b]	.316	.753	.043	.896	1.116	.771

a. Predictors in the Model: (Constant), B6

b. Predictors in the Model: (Constant), B6, B8

c. Dependent Variable: G1

Multiple linear regression analysis was conducted using SPSS to determine the coefficients in Equation (5.1) for each pattern parameter.

Before conducting the MLR analysis, each dependent variable (pattern parameters) was plotted against each independent variable (body parameters) to examine if the relationship follows some specific trends, such as exponential, logarithm, or sine. If so, the independent variable was firstly converted by applying a mathematical function so that there is a linear correlation between the dependent variable and the converted independent variable. However, no specific trends were found for all independent variables against the dependent variable. Consequently, the independent variables (body parameters) were used directly in the SPSS analysis to derive MLR equations.

5.4 Pattern Parameters and Body Measurements

5.4.1 Pattern Parameters

The measurements of the pattern parameters of 59 shirts are listed in Appendix II. Table 5.2 lists the mean value and range of these pattern parameters. In this table, the definition of the notation of each pattern parameter could be referred back to Fig. 5.1. The second column of table is the mean of each pattern parameter from 59 fitted shirts. The third column is the standard deviation of each pattern parameter. The forth and fifth column are the minimum measurement and maximum measurement of each pattern parameter respectively.

Fig. 5.1 Shirt Pattern Parameters

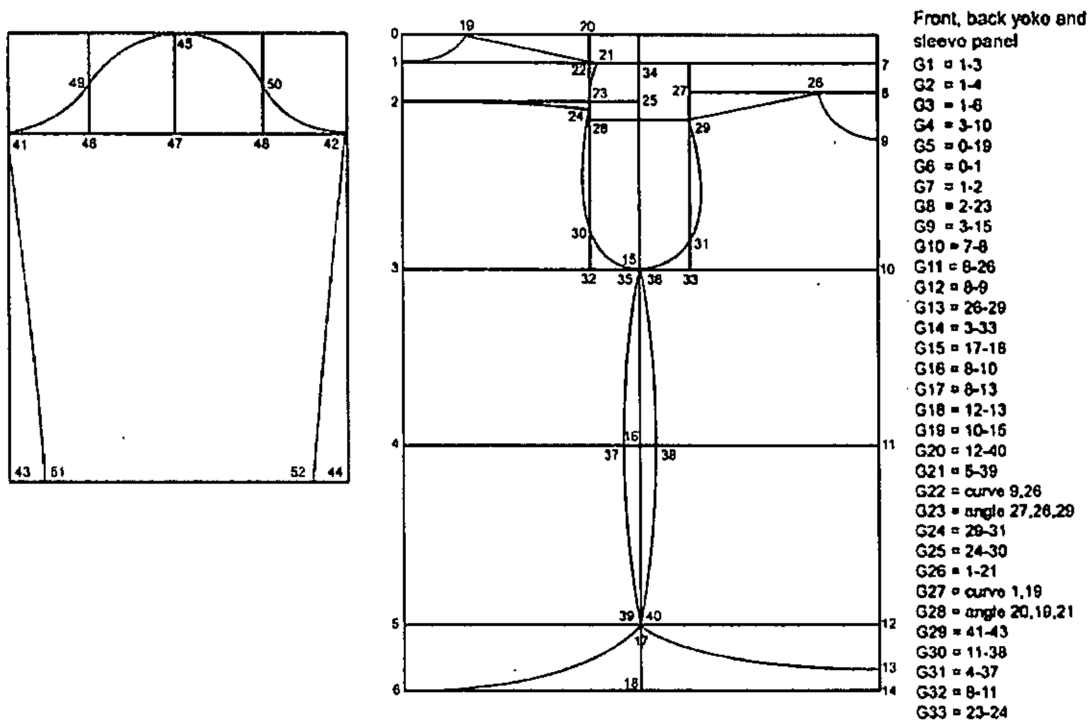


Table 5.2 Mean Value and Range of Pattern Parameters (in CM)

Pattern Parameters	Mean	SD	Min	Max
G_1	29.21	1.24	27.10	32.00
G_2	47.63	2.49	43.30	57.90
G_3	79.31	2.91	72.40	86.90
G_4	54.78	3.61	48.30	69.50
G_5	8.36	0.42	7.50	9.80
G_6	5.37	0.32	4.70	5.70
G_7	7.58	0.64	6.80	8.50
G_8	23.31	0.99	21.10	25.30
G_9	27.35	1.82	24.10	34.60
G_{10}	5.73	1.52	3.40	8.60
G_{11}	6.12	0.46	5.50	7.50
G_{12}	5.18	0.75	3.60	6.70
G_{13}	16.37	0.84	14.30	18.30
G_{14}	33.56	3.03	28.70	46.10
G_{15}	7.36	0.81	6.20	9.40
G_{16}	23.40	1.36	18.40	26.20
G_{17}	72.74	3.32	66.70	82.40
G_{18}	6.62	0.91	4.90	8.70
G_{19}	27.40	1.82	24.20	34.90
G_{20}	27.35	1.90	23.80	34.90
G_{21}	27.26	1.89	23.50	34.80
G_{22}	8.51	0.83	7.00	10.40
G_{23}	20.91	1.55	17.00	24.50
G_{24}	13.36	1.63	8.50	15.90
G_{25}	15.31	1.69	10.10	17.90
G_{26}	24.46	1.01	22.10	26.60
G_{27}	11.15	0.59	10.00	12.80
G_{28}	12.49	1.19	9.00	15.00
G_{29}	43.70	3.02	37.20	49.90
G_{30}	24.50	2.37	20.70	32.10
G_{31}	24.45	2.43	20.90	32.40
G_{32}	43.44	18.27	38.00	49.10
G_{33}	2.53	1.25	1.50	4.20

5.4.1 Body Parameters

The body measurements of 59 human subjects scanned from Techmath laser scanner are listed in Appendix I. Table 5.3 shows the mean values and ranges of these measurements. The first column of the table is the body parameters. The second column of the table is the description of each body parameter. The third column of table is the mean value of each body parameter from 59 subjects. The fourth column is the standard deviation of each body parameter. The fifth and sixth columns are the minimum measurement and maximum measurement of each body parameter respectively. Some of body measurements including neck girth, chest girth, waist girth, hip girth and arm length have been verified with manual measurements.

Table 5.3 Mean Value and Ranges of Body Parameters (in CM)

Body Parameters	Descriptions	Mean	SD	Min	Max
B_1	Body height	171.66	6.47	156.20	185.90
B_2	Head height	26.29	1.23	23.10	28.90
B_3	Distance neck to hip	60.36	2.74	54.80	67.60
B_4	Neck diameter	13.10	0.96	11.20	15.10
B_5	Mid neck girth	36.23	2.20	32.20	43.30
B_6	Side upper torso length	23.53	3.83	17.45	34.80
B_7	Torso width	33.87	4.38	23.60	45.70
B_8	Total torso girth	162.65	7.68	147.50	181.40
B_9	Cross shoulder over neck	38.50	2.83	32.10	44.50
B_{10}	Cross shoulder	42.08	3.26	35.10	48.60
B_{11}	1/2 Shoulder width	12.42	1.59	9.05	14.60
B_{12}	Shoulder angle L (°)	25.24	3.44	18.00	32.00
B_{13}	Shoulder angle R (°)	26.21	4.21	17.10	33.50
B_{14}	Cross front width	34.91	3.26	24.60	44.50
B_{15}	Breast width	38.66	3.32	31.80	46.10
B_{16}	Neck R to waist over bust	44.25	4.99	37.40	57.00
B_{17}	Neck front to waist over bust	34.55	5.55	26.60	48.10
B_{18}	Bust points around neck	70.11	6.05	56.30	86.60
B_{19}	Bust point to neck	26.76	3.21	20.05	39.90
B_{20}	Chest band	89.19	8.84	72.70	118.90
B_{21}	Midriff girth	83.58	7.95	71.00	113.10
B_{22}	Cross back width	36.01	2.34	32.40	41.90
B_{23}	Back width	36.47	2.61	32.00	44.90
B_{24}	Neck to underarm back	17.75	1.17	15.00	20.30
B_{25}	Back length	40.99	4.03	34.70	53.20
B_{26}	Back length over shoulder blade	44.82	3.70	38.45	56.65
B_{27}	Distance armpit-waist	22.46	4.07	16.70	34.90
B_{28}	Waist to hip back	21.35	3.39	12.40	27.40
B_{29}	Waist girth	76.32	8.55	63.90	104.50
B_{30}	Waist to hip	21.43	3.76	12.40	28.00
B_{31}	Hip girth	92.51	6.22	81.00	113.70
B_{32}	Arm length to neck back	80.50	3.36	72.25	87.80
B_{33}	Arm length to neck	73.63	3.43	65.40	80.60
B_{34}	Arm length	61.22	3.11	50.80	68.60

5.5 Prediction of Shirt Pattern by Multiple Linear Regression (MLR)

5.5.1 Classification of Body Parameters and Pattern Parameters

The general idea of using this statistical tool is to understand and establish the relationship between shirt pattern measurements and body measurements. In order to let the MLR to select the appropriate and reasonable independent variables (body parameters), the shirt pattern parameters and body parameters were classified into two categories, which were horizontal and vertical parameters.

The horizontal measurements in shirt pattern parameters were grouped together with horizontal body parameters for analysis. The vertical parameters of shirt patterns and body measurements were group together for analysis. This ensures that vertical body parameters were selected for predicting the vertical pattern parameters and horizontal parameters were selected for predicting the horizontal pattern parameters. Table 5.4 and 5.5 show the vertical and horizontal parameters of body measurements and patterns measurements.

Table 5.4 Vertical Parameters in Body Measurements and Pattern Measurements

Body Parameter		Pattern Parameter	
B_1	Body height	G_1	1-3
B_2	Head height	G_2	1-4
B_3	Distance neck to hip	G_3	1-6
B_6	Side upper torso length	G_6	0-1
B_8	Total torso girth	G_7	1-2
B_{16}	Neck R to waist over bust	G_{10}	7-8
B_{17}	Neck front to waist over bust	G_{12}	8-9
B_{18}	Bust points around neck	G_{15}	17-18
B_{19}	Bust point to neck	G_{16}	8-10
B_{24}	Neck to underarm back	G_{17}	8-13
B_{25}	Back length	G_{18}	12-13
B_{26}	Back length over shoulder blade	G_{24}	29-31
B_{27}	Distance armpit-waist	G_{25}	24-30
B_{28}	Waist to hip back	G_{29}	41-43
B_{30}	Waist to hip	G_{32}	8-11
B_{32}	Arm length to neck back	G_{33}	23-24
B_{33}	Arm length to neck		
B_{34}	Arm length		

Table 5.5 Horizontal Parameters in Body Measurements and Pattern Measurements

Body Parameter		Pattern Parameter	
B_4	Neck diameter	G_4	3-10
B_5	Mid neck girth	G_5	0-19
B_7	Torso width	G_8	2-23
B_9	Cross shoulder over neck	G_9	3-15
B_{10}	Cross shoulder	G_{11}	8-26
B_{11}	1/2 Shoulder width	G_{13}	26-29
B_{12}	Shoulder angle L (°)	G_{14}	3-33
B_{13}	Shoulder angle R (°)	G_{19}	10-15
B_{14}	Cross front width	G_{20}	12-40
B_{15}	Breast width	G_{21}	5-39
B_{20}	Chest band	G_{22}	9,26
B_{21}	Midriff girth	G_{23}	Angle 27,26,29
B_{22}	Cross back width	G_{26}	1-21
B_{23}	Back width	G_{27}	1,19
B_{29}	Waist girth	G_{28}	Angle 20,19,21
B_{31}	Hip girth	G_{30}	11-38
		G_{31}	4-37

5.5.2 Prediction Equations from Multiple Linear Regression (MLR)

Table 5.6 lists the prediction equations for each pattern parameter derived from Multiple Linear Regression and the squared correlation coefficient. The pattern parameters with a mark are the vertical parameters, otherwise they are horizontal pattern parameters. It shows that most of the pattern parameters are correlated with several body parameters and the correlation coefficients are generally very high.

Table 5.6 Equations of Shirt Pattern Parameters from Multiple Linear Regression

Pattern Parameter	Equation from Multiple Linear Regression	Correlation R^2
*G_1	$22.959 - 0.194B_6 + 0.06659B_8$	0.30
*G_2	$22.613 + 0.215B_8 + 0.08599B_{30} - 0.36B_{27} - 0.253B_{28}$	0.60
*G_3	$28.063 + 0.131B_{30} + 0.131\ B_8 + 0.304\ B_{32}$	0.70
G_4	$3.461 + 0.198B_{21} + 0.172B_{31} + 0.233B_{15} + 0.274B_{22}$	0.90
G_5	$3.829 + 0.06175B_9 + 0.05957B_5$	0.40
*G_6	$4.735 - 0.0259B_{17} + 0.09095B_{33} - 0.0844B_{34}$	0.70
*G_7	$8.62 + 0.04054B_{30} - 0.0792B_{17}$	0.70
G_8	$8.165 + 0.0566B_{31} + 0.163B_{23} + 0.05576B_{13} + 0.07124B_{14}$	0.70
G_9	$1.59 + 0.09889B_{21} + 0.09377B_{31} + 0.114B_{15} + 0.123B_{22}$	0.90
*G_{10}	$10.992 - 0.224B_{17} + 0.05944B_{30}$	0.60
G_{11}	$0.107 + 0.166B_5$	0.60
*G_{12}	$-0.597 - 0.0338B_{30} + 0.203B_5 + 0.06355B_{17} - 0.0321B_{33}$	0.70
G_{13}	$9.699 + 0.185B_{22}$	0.30
G_{14}	$5.059 + 0.341B_{21}$	0.80
*G_{15}	$4.871 + 0.167B_{17} - 0.0265B_{30} - 0.0967B_{27}$	0.50
*G_{16}	$9.211 + 0.09652B_8 + 0.153B_6 - 0.239B_3 + 0.116B_{32}$	0.40
*G_{17}	$20.483 + 0.217B_8 + 0.212B_{17} + 0.39B_{34} + 0.06097B_{30} - 0.279B_3$	0.70
*G_{18}	$3.059 + 0.193B_{17} - 0.0246B_{30} - 0.093B_{27}$	0.60
G_{19}	$2.413 + 0.108B_{21} + 0.0894B_{31} + 0.109B_{15} + 0.9646B_{22}$	0.90
G_{20}	$5.036 + 0.143B_{31} + 0.109B_{21}$	0.80
G_{21}	$5.752 + 0.118B_{21} + 0.126B_{31}$	0.80
G_{22}	$0.119 + 0.224B_5 - 0.151B_{11} + 0.02429B_{20}$	0.70
G_{23}	$24.139 + 0.179B_{12} - 0.0838B_{31}$	0.30
*G_{24}	$7.549 + 0.323B_{28} + 0.157B_6 - 0.0683B_{18}$	0.40
*G_{25}	$7.694 + 0.12B_{28} + 0.756B_{33} - 0.628B_{32}$	0.40
G_{26}	$12.417 + 0.181B_{22} + 0.05971B_{31}$	0.50
G_{27}	$6.291 + 0.172B_9 - 0.0195B_{20}$	0.50
G_{28}	$24.178 - 0.448B_4 - 0.104B_{31} + 0.11B_{14}$	0.60
*G_{29}	$-17.007 + 0.569B_{33} + 0.08707B_{30} - 0.122B_{17} + 0.113B_1$	0.90
G_{30}	$6.06 + 0.242B_{29}$	0.80
G_{31}	$5.491 + 0.248B_{29}$	0.80
*G_{32}	$24.749 + 0.1B_{30} + 0.086B_8$	0.40
*G_{33}	$4.912 - 0.106B_6$	0.30

***Vertical Pattern Parameters**

The highest correlation R^2 is 0.9, which are for the pattern parameters G_4 (3-10), G_9 (3-15), G_{19} (10-15) and G_{29} (41-43). They are the half chest girth, back chest girth, front chest girth and sleeve length from shoulder respectively. The second highest correlation R^2 is 0.8, which are for the pattern parameters G_{14} (3-33), G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the two-third of the chest girth, front hip girth, back hip girth, front waist girth and back waist girth, respectively.

In traditional pattern drafting formulae, G_4, G_9 and G_{19} are calculated only from the chest girth. However, MLR analysis showed that they are correlated with B_{21} (midriff girth), B_{31} (hip girth), B_{15} (breast width) and B_{22} (cross back). In other words, these pattern parameters are explained by several girth measurements with different amount of proportion.

As can be seen, G_{29} can be predicted from B_{33} (arm length to neck), B_{30} (waist to hip), B_{17} (neck front to waist over bust) and B_1 (body height). It is believed that G_{29} is not only correlated to arm length, but also a proportion of body height, the certain amount of waist to hip measurements and a proportion of neck front to waist over bust.

Comparing the results listed in Table 5.6 and those in Tables 4.7 to 4.10, the pattern prediction equations from the multiple linear regression are clearly better than the experts' formula in calculating the shirt pattern measurements from the body parameters. For instance, the R^2 of pattern parameters G_2, G_6, G_7, G_{10}, G_{28} increased from 0.00 to more than 0.6.

Compared with traditional pattern drafting formulae, the prediction equations from MLR sometimes use different body parameters to predict the pattern parameters. For example, G_2 (1-4) is predicted from the B_8 (total torso girth), B_{30} (waist to hip), B_{27} (distance armpit-waist) and B_{28} (waist to hip back). Whereas, in the traditional drafting methods, G_2 (1-4) is calculated from either scye depth or chest girth to determine the measurement of this parameter. G_6 (0-1) is predicted from B_{17} (neck front to waist over bust), B_{33} (arm length to neck) and B_{34} (arm length) in the MLR model. However, the traditional pattern drafting formulae either use the neck girth to determine this parameter or just estimate a fixed value. G_7 (1-2) and G_{10} (7-8), are predicted from B_{30} (waist to hip) and B_{17} (neck front to waist over bust) in the MLR model, but in the traditional pattern drafting methods, they are calculated from chest girth.

For some pattern parameters, no formulae were available in the traditional pattern drafting methods, but prediction equations are now established through MLR analysis. For example, G_{28} can now be predicted from B_4 (neck diameter), B_{31} (hip girth) and B_{14} (cross front width), whereas no exact formula to determine the back shoulder angle from the existing pattern drafting methods.

Through Multiple Linear Regression analysis, it is shown that one pattern parameter may be explained by several body parameters. Single body parameter is not adequate to predict the pattern parameter accurately. The traditional pattern drafting methods from tailoring experts cannot directly produce fitting shirts for target customer because they generally use one body parameter to calculate one pattern parameter.

It was also found that the correlated body parameters of each pattern parameter are mainly located at surrounding positions. It is believed that the shape of the human body in its three-dimensional form affects the pattern design.

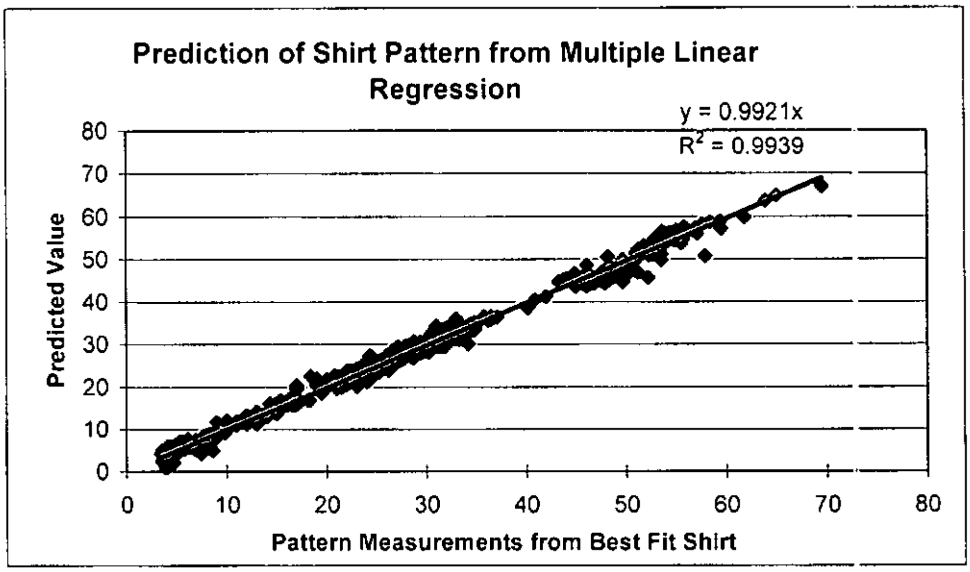
5.6 Correlation between Predicted Pattern Measurements and Actual Pattern Measurements of Fitting Shirts

5.6.1 The Predicted Pattern Measurements from MLR Equations Vs the Actual Pattern Measurements of Fitting Shirts

If the prediction of pattern measurements is good, the deviations between the predicted values should be relative small when plotted against the actual pattern measurements of the fitting shirts.

The predicted pattern measurements from multiple linear regression equations are plotted against the actual shirt pattern measurements in Fig. 5.2. As can be seen, the correlation (R^2) is 0.99. This means that the deviation between actual shirt pattern measurements and predicted values from the MLR equations is relative small.

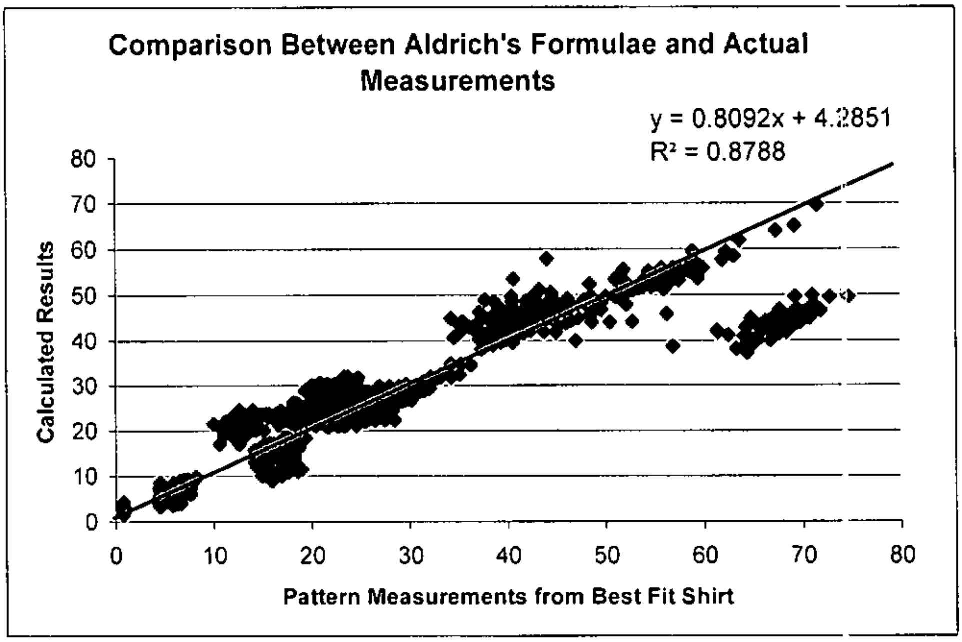
Fig. 5.2 Comparison between Predictive Results from Multiple Linear Regression and Actual Shirt Pattern Measurements



5.6.2 The Predicted Pattern Measurements from Aldrich's Formulae VS the Actual Shirt Measurements

The calculated pattern measurements from Aldrich's formulae and the actual shirt pattern measurements are compared and plotted in Fig. 5.3. Although the squared correlation coefficient (R^2) is 0.87, the deviations between calculated pattern measurements and pattern measurements from best fit shirts are high. It confirms the findings discussed in the previous Chapter that the prediction from Aldrich's formulae is not accurate enough for making fitting shirt patterns.

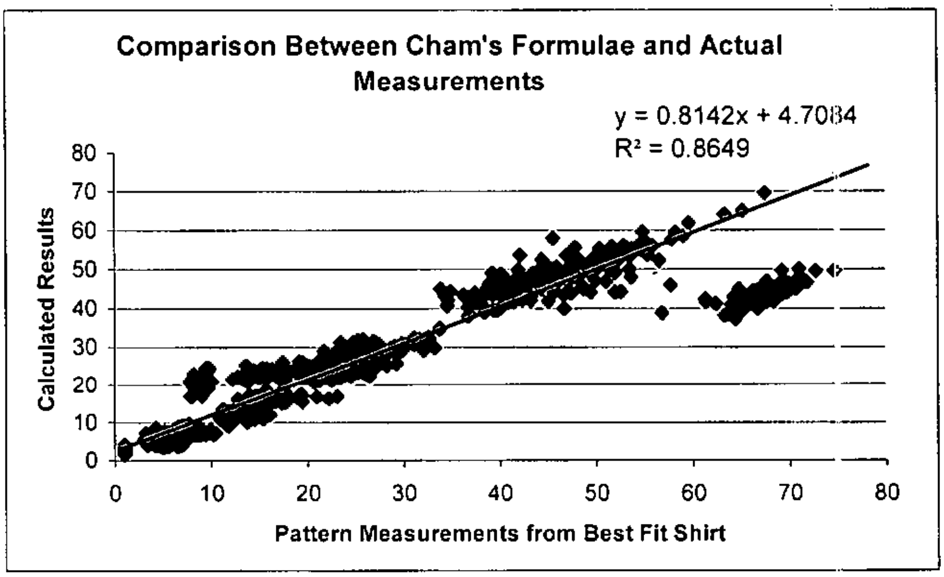
Fig. 5.3 Comparison between Aldrich's Formulae and Actual Shirt Pattern Measurements



5.6.3 The Predicted Pattern Measurements from Cham's Formulae VS the Actual Shirt Measurements

The calculated pattern measurements from Cham's formulae and the actual shirt pattern measurements are compared and plotted in Fig. 5.4. Although the squared correlation coefficient (R^2) is 0.86, the deviations between calculated pattern measurements and pattern measurements from best fit shirts are high. It confirms the findings discussed in the previous Chapter that the prediction from Cham's formulae is not accurate enough for making fitting shirt patterns.

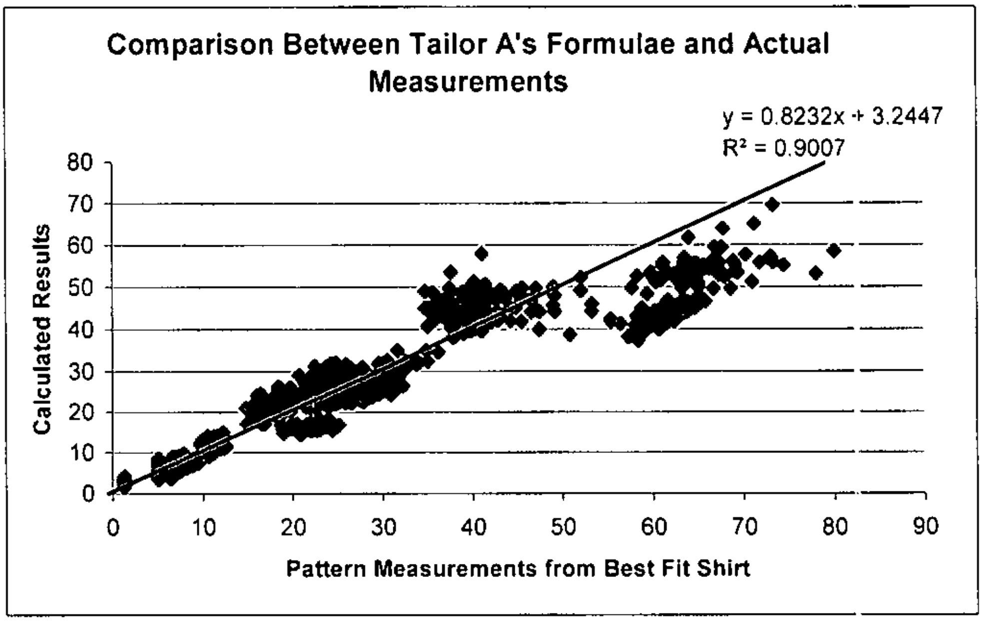
Fig. 5.4 Comparison between Cham's Formulae and Actual Shirt Pattern Measurements



5.6.4 The Predicted Pattern Measurements from Tailor A's Formulae VS the Actual Shirt Measurements

The calculated pattern measurements from Tailor A's formulae and the actual shirt pattern measurements are compared and plotted in Fig. 5.5. Although the squared correlation coefficient (R^2) is 0.9, the deviations between calculated pattern measurements and pattern measurements from best fit shirts are high. It confirms the findings discussed in the previous Chapter that the prediction from Tailor A's formulae is not accurate enough for making fitting shirt patterns.

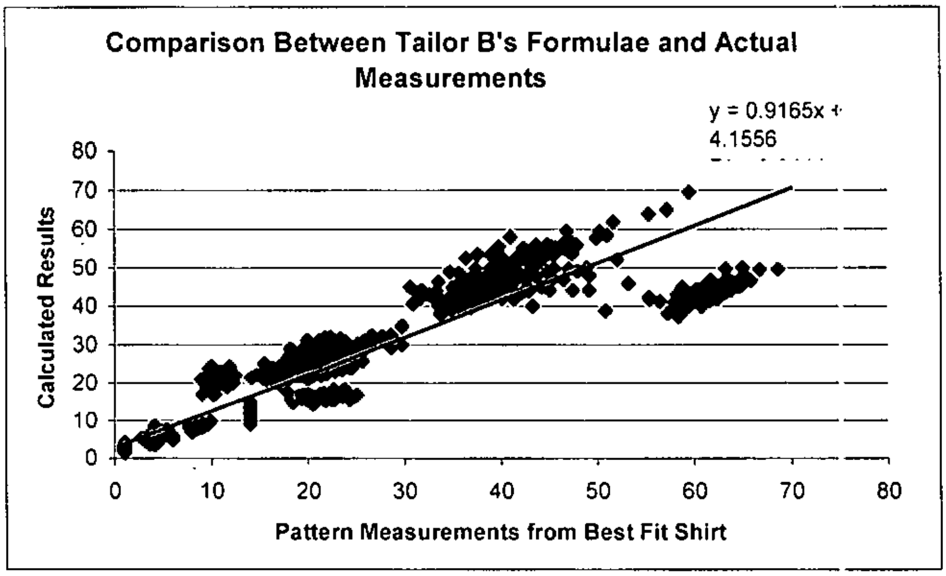
Fig. 5.5 Comparison between Tailor A's Formulae and Actual Shirt Pattern Measurements



5.6.5 The Predicted Pattern Measurements from Tailor B's Formulae VS the Actual Shirt Measurements

The calculated pattern measurements from Tailor B's formulae and the actual shirt pattern measurements are compared and plotted in Fig. 5.6. Although the squared correlation coefficient (R^2) is 0.84, the deviations between calculated pattern measurements and pattern measurements from best fit shirts are high. It confirms the findings discussed in the previous Chapter that the prediction from Tailor B's formulae is not accurate enough for making fitting shirt patterns.

Fig. 5.6 Comparison between Tailor B's Formulae and Actual Shirt Pattern Measurements



5.7 Comparison of Multiple Linear Regression Equations and Tailoring Experts Formulae in terms of Squared Correlation Coefficient (R^2)

Squared correlation coefficient is an indicator of the accuracy and predictability of the prediction equation. Table 5.7 lists the squared correlation coefficients for each pattern parameter for both tailoring experts' formulae and multiple linear regression equations. As can been seen, in most cases, MLR equations have significantly better prediction than the tailoring experts' formulae.

Table 5.7 Comparison of Correlation (R^2) between 4 Tailoring Experts and the Predicted Results from Multiple Linear Regression

Pattern Parameters	Aldrich	Cham	Tailor A	Tailor B	Multiple Linear Regression
G_1	0.15	0.07	0.07	0.07	0.3
G_2	**0.01**	**0.01**	**0.01**	**0.01**	**0.6**
G_4	0.79	0.79	0.22	0.79	0.9
G_5	0.25	0.25	0.17	0.25	0.4
G_6	**0.00**	**0.00**	**0.00**	**0.00**	**0.7**
G_7	**0.03**	**0.05**	**0.00**	**0.00**	**0.7**
G_8	**0.38**	**0.32**	**0.38**	**0.26**	**0.7**
G_9	0.80	0.80	0.80	0.80	0.9
G_{10}	**0.00**	**0.04**	**0.00**	**0.00**	**0.6**
G_{11}	0.64	0.64	0.50	0.64	0.6
G_{12}	**0.29**	**0.15**	**0.25**	**0.31**	**0.7**
G_{13}	0.23	0.05	0.17	0.17	0.3
G_{16}	0.02	0.28	0.06	0.28	0.4
G_{19}	0.81	0.81	0.81	0.81	0.9
G_{20}	0.68	0.68	0.74	0.68	0.8
G_{21}	0.68	0.68	0.70	0.68	0.8
G_{23}	0.02	0.08	0.05	0.05	0.3
G_{26}	0.40	0.19	0.37	0.36	0.5
G_{28}	**0.01**	**0.02**	**0.04**	**0.00**	**0.6**
G_{29}	0.59	0.59	0.59	0.59	0.9
G_{30}	0.61	0.61	0.61	0.61	0.8
G_{31}	0.62	0.62	0.62	0.62	0.8
G_{32}	0.13	0.16	0.13	0.13	0.4
G_{33}	0.00	0.00	0.00	0.00	0.3

5.8 Deviations of Multiple Linear Regression Equations

Table 5.8 shows the deviations of MLR's formulae. The highest correlation (R^2) is around 0.9, those pattern parameters are G_4 (3-10), G_9 (3-15) G_{19} (10-15) and G_{29} (41-43). They are the half chest girth, back chest girth, front chest girth and sleeve length respectively. For G_4, the mean error is –0.01 cm; the standard deviation is 1.18 cm and the maximum deviation based on 95% confidence limit can be 4.23%. For G_9, the mean error is –0.02 cm; the standard deviation is 0.58 cm and the maximum deviation based on 95% confidence limit can be 4.19%. For G_{19}, the mean error is 0.00 cm; the standard deviation is 0.60 cm and the maximum deviation based on 95% confidence limit can be 4.28%. For G_{29}, the mean error is 1.77 cm; the standard deviation is 1.63 cm and the maximum deviation based on 95% confidence limit can be 11.34%.

The second high correlation (R^2) is around 0.80, those parameters are the G_{20} (12-40), G_{21} (5-39), G_{30} (11-38) and G_{31} (4-37). They are the front hip girth, back hip girth, front waist girth and back waist girth respectively. For G_{20}, the mean error is –0.03 cm; the standard deviation is 0.87 cm and the maximum deviation based on 95% confidence limit can be 6.32%. For G_{21}, the mean error is –0.01 cm; the standard deviation is 0.91 cm and the maximum deviation based on 95% confidence limit can be 6.61%. For G_{30}, the mean error is –0.03 cm; the standard deviation is 1.16 cm and the maximum deviation based on 95% confidence limit can be 9.39%. For G_{31}, the mean error is 0.03 cm; the standard deviation is 1.19 cm and the maximum deviation based on 95% confidence limit can be 9.68%.

It shows that the deviations of Multiple Linear Regression formulae are less than the deviations generated from four different tailoring experts' formulae. It proves that the Multiple Linear Regression enhance the accuracy on shirt pattern drafting.

Table 5.8 Deviation of MLR's Formulae between Pattern Measurements of Best Fit Shirts and Those Calculated from MRL's Formulae

Pattern Parameters	Deviation of MLR's Formulae					Correlation (R^2)
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)	
G_1	29.21	1.01	-0.02	-1.99~1.96	-6.82~6.71	0.3
G_2	47.63	2.03	1.69	-2.29~5.67	-4.81~11.91	0.6
G_4	54.78	1.18	-0.01	-2.31~2.29	-4.23~4.18	0.9
G_5	8.36	0.33	0.00	-0.64~0.64	-7.70~7.70	0.4
G_6	5.37	0.17	0.00	-0.33~0.34	-6.21~6.24	0.7
G_7	7.58	0.65	0.83	-0.45~2.10	-5.89~27.71	0.7
G_8	23.31	0.57	0.02	-1.10~1.14	-4.73~4.88	0.7
G_9	27.35	0.58	-0.02	-1.15~1.11	-4.19~4.07	0.9
G_{10}	5.73	1.20	1.20	-1.14~3.55	-19.93~61.89	0.6
G_{11}	6.12	0.27	0.00	-0.53~0.53	-8.73~8.73	0.6
G_{12}	5.18	0.60	-0.68	-1.85~0.49	-35.72~9.43	0.7
G_{13}	16.37	0.72	0.01	-1.40~1.41	-8.54~8.63	0.3
G_{16}	23.40	1.03	-0.02	-2.04~2.00	-8.71~8.54	0.4
G_{19}	27.40	0.60	0.00	-1.16~1.17	-4.25~4.28	0.9
G_{20}	27.35	0.87	-0.03	-1.73~1.67	-6.32~6.11	0.8
G_{21}	27.26	0.91	-0.01	-1.80~1.78	-6.61~6.52	0.8
G_{23}	20.91	1.34	0.00	-2.62~2.62	-12.52~12.54	0.3
G_{26}	24.46	0.72	0.00	-1.41~1.41	-5.76~5.75	0.5
G_{28}	12.49	0.79	-0.04	-1.59~1.52	-12.73~12.16	0.6
G_{29}	43.70	1.63	1.77	-1.42~4.95	-3.26~11.34	0.9
G_{30}	24.50	1.16	-0.03	-2.30~2.25	-9.39~9.18	0.8
G_{31}	24.45	1.19	0.03	-2.30~2.37	-9.40~9.68	0.8
G_{32}	42.93	2.31	2.05	-2.47~6.58	-5.76~15.33	0.4
G_{33}	2.41	0.58	-0.01	-1.15~1.12	-47.64~46.70	0.3

Note: a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error + 1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

5.9 Conclusions

Multiple Linear Regression model is a very good tool to establish the relationship between body parameters and pattern parameters. Besides, it reveals and proves that the pattern parameters are correlated with several body parameters. This could be one of the major reasons that the tradition drafting formulae could not accurately predict the pattern parameters of best-fit shirts.

All pattern parameters predicted from the multiple linear regression equations have relatively high correlation (R^2) with the actual pattern measurements of best-fit shirts than those calculated from the four tailoring experts' formulae. Although the pattern prediction has been improved by MLR, the prediction is still not prefect. The reasons might be due to the fact that pattern parameters are not only correlated with several body parameters, but the correlation may be nonlinear, as human body is in three-dimensional form. Mathematical tools for modeling the nonlinear interrelationship are therefore desirable in further research.

Chapter 6

Prediction of Men's Shirt Pattern from 3D Body Measurements Using Artificial Neural Network

Chapter 6

Prediction of Men's Shirt Pattern from 3D Body Measurements Using Artificial Neural Network

6.1 Introduction

Although Multiple Linear Regression equations reported in the previous Chapter has improved the prediction of men's shirt pattern parameters in comparison with the tailoring experts' formulae, the prediction is still not sufficiently accurate for automatic pattern drafting. This may be due to the fact that the relationship between pattern parameters and body parameters is generally non-linear. In order to further enhance the accuracy of pattern prediction, Artificial Neural Network (ANN) was applied. ANN is an effective tool for building non-linear models.

In this Chapter, the architecture and the algorithm of the ANN are described. The application of ANN for shirt pattern prediction is reported and the accuracy of the ANN model is discussed.

6.2 Nomenclature

x = Input training vector:

$x = (x_1, \ldots, x_i, \ldots, x_n)$

t = Output target vector

$t = (t_1, \ldots, t_k, \ldots, t_m)$

δ_k = Portion of error correction weight adjustment for w_{jk} that is due to an error at output unit Y_k; also, the information about the error at unit Y_k that is propagation back to the hidden units that feed into unit Y_k.

δ_j = Portion of error correction weight adjustment for v_{ij} that is due to the backpropagation of error information from the output layer to the hidden unit Z_j.

α = Learning rate

X_i = Input unit i:

For an input unit, the input signal and output signal are the same, namely, x_i

v_{oj} = Bias on hidden unit j.

Z_j = Hidden unit j:

The net input to Z_j is denoted z_in_j:

$$z\_in_j = v_{oj} + \sum_i x_i v_{ij}$$

The output signal (activation) of Z_j is denoted z_j:

$$z_j = f(z\_in_j).$$

w_{ok} = Bias on output unit k.

Y_k = Output unit k.

The net input to Y_k is denoted y_in_k:

$$y\_in_k = w_{ok} + \sum_j z_j w_{jk}$$

The output signal (activation) of Y_k is denoted y_k :

$$y_k = f(y\_in_k)$$

B' = Converted value of each body parameter

B = Original value of each body measurement

B_{min} = Minimum value of each body measurement

B_{max} = Maximum value of each body measurement

G' = Converted value of each pattern parameter / Predicted value of each pattern parameter

G = Original value of each pattern measurement / Pattern value in normal measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

6.3 Definition of Artificial Neural Network (ANN)

6.3.1 Basic Principles of Pattern Prediction Using ANN

Artificial neural network (ANN) is a useful mathematical approach for the establishment of the prediction models. Past research has discovered that ANN is especially effective for modeling nonlinear functions or relationships (Fausett 1994, Fan and Hunter 1998, Fan et al 2001). The principle of ANN is to train the model (i.e. adjusting the weights between the nodes in each layer) using experimental datasets so that the output from the ANN is equal or as close as possible to the target pattern. For the present application, G (Pattern Parameters) are the output parameters, whereas P (Perception of Fitting) and B (Body Parameters) are input parameters. The ANN training and application program were written in C programming language. The programs are listed in Appendix V and VI respectively. The parameters of the ANN model for the present investigation is listed at Table 6.1

Table 6.1 Parameters of Artificial Neural Network Model

Activation function at output layer	$f(x)=\frac{1}{1+e^{-x}}$
Activation function at hidden layer	$f(x)=\frac{1}{1+e^{-x}}$
Input parameters	34 body parameters
Output parameters	33 shirt pattern parameter
Number of hidden units	80
Number of training pairs	50
Number of cross-checking pairs	9

6.3.2 Architecture

A backpropagation multi-layer neural network with one layer of hidden units (the Z units) as shown in Fig. 6.1 is applied in this study. The output units (the Y units) and the hidden units have biases. These biases act like weights on connections from units whose output is always 1. These are usually not displayed explicitly. Only the direction of information flow for the feedforward phase of operation is shown. During the backpropagation phase of learning, signals are sent in the reverse direction. It is simply a gradient descent method to minimize the total squared error of the output computed by the net.

6.3.3 Algorithm

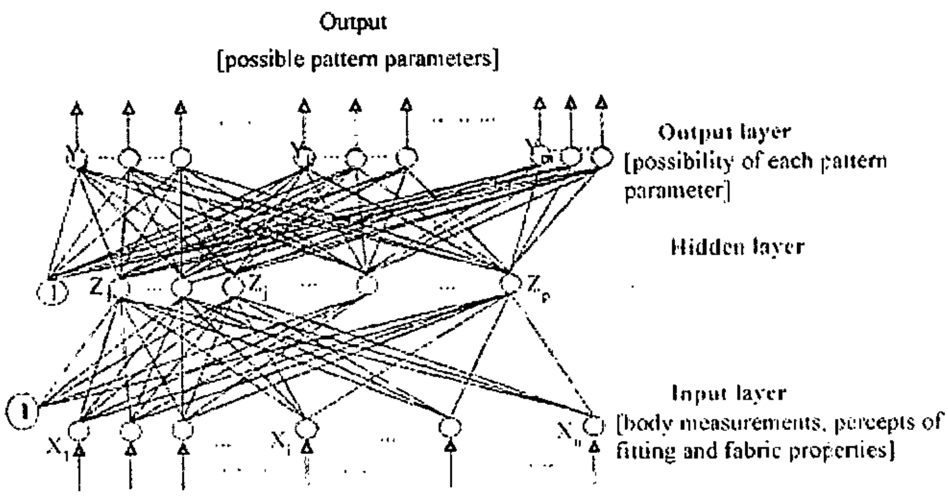
Training a network by backpropagation involves three stages: the feedforward of the input training pattern, the backpropagation of the associated error, and the adjustment of the weights.

During feedforward, each input (X_i) receives an input signal and broadcasts this signal to each of the hidden units $Z_1,\cdots,Z_p$. Each hidden unit then computes its activation and sends its signal (z_j) to each output unit. Each output unit (Y_k) computes its activation (y_k) to form the response of the net for the given input pattern.

During training, each output units compares its computed activation y_k with its target value t_k to determine the associated error for that pattern with that unit. Based on this error, the factor $\delta_k (k = 1,\cdots,m)$ is computed. δ_k is used to distribute the error at output unit Y_k back to all units in the previous layer (the hidden units that are connected to Y_k). It is also used (later) to update the weights between the output and the hidden layer. In a similar manner, the factor $\delta_j (j = 1,\cdots,p)$ is computed for each hidden unit Z_j. It is not necessary to propagate the error back to the input layer, but δ_j is used to update the weights between the hidden layer and the input layer.

After all of the δ factors are determined, the weights for all layers will be adjusted simultaneously. The adjustment to the weight (from hidden unit Z_j to output unit Y_k) is based on the factor δ_k and the activation z_j of the hidden unit Z_j. The adjustment to the weight (from input unit X_i to hidden unit Z_j) is based on factor δ_j and the activation x_i of the input unit.

Fig. 6.1 Backpropagation Neural Network with One Hidden Layer



6.3.4 Activation Function

An activation for a backpropagation net should have several important characteristics: It should be continuous, differentiable, and monotonically non-decreasing. Furthermore, for computational efficiency, it is desirable that its derivative be easy to compute. For the most commonly used activation functions, the value of the derivative (a particular value of the independent variable) can be expressed in terms of the values of the function (at that value of the independent variable). Usually, the function is expected to saturate, i.e., approach finite maximum and minimum values asymptotically.

One of the most typical activation functions is the binary sigmoid function, which has the range of $(0,1)$ and is defined as

$$f_1(x) = \frac{1}{1+\exp^{(-x)}}$$

with $f_1'(x) = f_1(x)[1 - f_1(x)]$

The above activation function was used in the standard backpropagation algorithm applied in this study. The function was chosen because of the form of the data (especially the target values) was continuous, and because of the simple relationship between the value of the function and its derivative.

6.3.5 Training Algorithm

In this study, C language was used for writing a program for ANN training and ANN application. The training program and application program are listed on Appendix V and VI respectively.

The algorithm is as follows:

Step 0. Initialize weights

(Set to small random values)

Step 1. While stopping condition is false, do Step 2-9

Step 2. For each training pair, do Step 3-8

Feedforward:

Step 3. Each input unit $(X_i, i = 1,...,n)$ receives input signal x_i and broadcasts this signal to all units in the layer above (the hidden units)

Step 4. Each hidden unit $(Z_j, j = 1,..., p)$ sums its weighted input signals,

$$z\_in_j = v_{oj} + \sum_{i=1}^{n} x_i v_{ij}$$

applies its activation function to compute its output signal,

$$z_j = f(z\_in_j),$$

and sends this signal to all units in the layer above output units).

Step 5. Each output unit $(Y_k, k = 1,..., m)$ sums its weighted input signals,

$$y\_in_k = w_{ok} + \sum_{j=1}^{p} z_j w_{jk}$$

and applies its activation function to compute its output signal,

$$y_k = f(y\_in_k)$$

Backpropagation of error:

Step 6. Each output unit $(Y_k, k-1,...,m)$ receives a target pattern corresponding to the input training pattern, computes its error information term,

$$\delta_k = (t_k - y_k) f'(y\_in_k)$$

calculates its weight correction term (used to update w_{jk} later),

$$\Delta w_{jk} = \alpha \delta_k z_j.$$

calculates its bias correction term (used to update w_{ok} later),

$$\Delta w_{ok} = \alpha \delta_k ,$$

and send δ_k to units in the layer below.

Step 7. Each hidden unit $(Z_j, j-1,..., p)$ sums its delta inputs (from units in the layer above),

$$\delta\_in_j = \sum_{k=1}^{m} \delta_k w_{jk}$$

multiplies by the derivative of its activation function to calculate its error information term.

$$\delta_j = \delta\_in_j f'(z\_in_j),$$

calculates its weight correction term (used to update v_{ij} later),

$$\Delta v_{ij} = \alpha \delta_j x_i.$$

and calculates its bias correction term)used to update v_{oj} later),

$$\Delta v_{oj} = \alpha\delta_j$$

Update weights and biases:

Step 8. Each output unit $(Y_k, k = 1,...,m)$ updates its bias and weights $(j = 0,...,p)$:

$$w_{jk}(new) = w_{jk}(old) + \Delta w_{jk}$$

Each hidden unit $(Z_j, j = 1,...,p)$ updates its bias and weights $(i = 0,...,n)$:

$$v_{ij}(new) = v_{ij}(old) + \Delta v_{ij}$$

Step 9. Test stopping condition.

Note that in implementing this algorithm, separate arrays should be used for the deltas for the output units (Step 6, δ_k) and the deltas for the hidden units (Step7, δ_j).

An epoch is one cycle through the entire set of training vectors. Typically, many epochs are required for training a backpropagation neural net. The foregoing algorithm updates the weights after each training pattern is presented. A common variation is batch updating, in which weight updates are accumulated over an entire epoch (or some other number of presentations of patterns) before being applied.

Note that $f'(y\_in_k)$ and $f'(y\_in_j)$ can be expressed in terms of y_k and z_j, respectively.

The mathematical basis for the backpropagation algorithm is the optimization technique known as gradient descent. The gradient of a function (in this case, the function is the error and the variables are the weights of the net) gives the direction in which the function increases more rapidly; the negative of the gradient gives the direction in which the function decreases most rapidly. The derivation clarifies the reason why the weight updates should be done after all of the δ_k and δ_j expressions have been calculated, rather than during backpropagation.

6.4 Parameters in the ANN Program

6.4.1 Input, Output and Hidden Units

In this pattern prediction model, the input units are body parameters that are important to shirt pattern drafting. The output units are the patterns parameters. The current network has thirty-four inputs units and thirty-three output units. The parameters are summarized in Table 6.1. Those thirty-four body parameters are the upper body measurements from 59 subjects obtained from body scanning and are believed to be necessary and sufficient for shirt pattern drafting.

The number of hidden units is very important for the performance of model. Too many hidden units would cause unacceptably long training times, losing the generalization capability of the model. There are no proven algorithms for determining the optimum number of hidden units. Therefore, the best way was to determine it by frequent trials and errors. In this model, a large number of computational experiments have been done for investigating the appropriate number of hidden units that would produce a low prediction error. It found that 80 hidden units were to be adequate.

6.4.1.1 Conversion of Input and Output Units

The data were scaled down to be within (0,1) to avoid the overfloat problem in computation. Output data were also scaled down to be within (0,1) to correspond to the output range of the binary sigmoid activation function, which has been shown in section 6.3.4.

The following equations were used to convert the original data to the scaled down data in order to ensure the scaled down data are spread within (0.1) range.

For body parameters:

$$B' = \frac{B - B_{min}}{B_{max} - B_{min}} \times 0.8 + 0.1 \qquad (6.1)$$

where,

B'	= Converted value of each body parameter
B	= Original value of each body measurement
B_{min}	= Minimum value of each body measurement
B_{max}	= Maximum value of each body measurement

For pattern parameters:

$$G' = \frac{G - G_{min}}{G_{max} - G_{min}} \times 0.8 + 0.1 \qquad (6.2)$$

Where,

G' = Converted value of each pattern parameter

G = Original value of each pattern measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

For converting back the results to original scale:

$$G = [\frac{(G'-0.1)}{0.8} \times (G_{max} - G_{min})] + G_{min} \qquad (6.3)$$

where,

G' = Predicted value of each pattern parameter

G = Pattern value in normal measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

The Equations 6.1 and 6.2 were used to ensure the data within the range from 0 to 1. If the input data is the maximum value, the numerator is same as the denominator then the final value become 0.9. If the input data is the minimum value, the denominator is zero then the final value become 0.1

The scaled data was then written into a data file format, named "input.dat" for program training. The sequence of the data in this file is such that the 34 body parameters and 33 pattern parameters were listed from left to right for each subject. From top to bottom, it was the number of training sets. In this case, the training sets of data were 50 out of 59 subjects. The rest of 9 sets of data were used as the cross-validation set and which will be discussed in the coming section.

6.4.2 Training Sets and Cross-checking Sets

According to Hecht-Nielsen (1990), it is not necessarily advantageous to continue training until the total squared error actually reaches the minimum. He suggested to use two sets of data during training: a set of training patterns (input unit) and a set of training-testing patterns (checking pairs). Weight adjustments are based on the training patterns; however, at intervals during training, the error is computed using the training-testing patterns. As long as the error for the training-testing patterns decreases, training continues. When the error of the checking pairs is too high, the net memorizes the training patterns too specifically (and starting to lose its ability to generalize). At this point, training is matured and needed to be terminated." This strategy is used in the training program of the present study.

Number of checking pairs is an issue. Since there is no established guideline on the optimum number of checking pairs for ANN training. A general rule is that at least one-tenth of total training data is used as checking pairs. Therefore, in this case, training pairs of data were decided to be 50 out of 59 pairs of data. The rest of 9 sets of data were used as the training-testing patterns (checking pairs). The file names of those two sets of data were "input.dat" and "checking.dat". The total number of those two sets of data was the training pairs of program. All these information was needed to perform the ANN program.

6.4.3 Learning Rate

Learning rate is the training speed of program, too high in learning rate will result in poor performance of the model, too low will result in excessive slow training process. An adequate speed is important for ANN training. Since there is no proven algorithm to determine the optimum number of this learning rate, this was therefore estimated by trials and errors. Preliminary computational experiments showed a learning rate of 0.01 is adequate for the present case.

6.4.4 Initial Weights

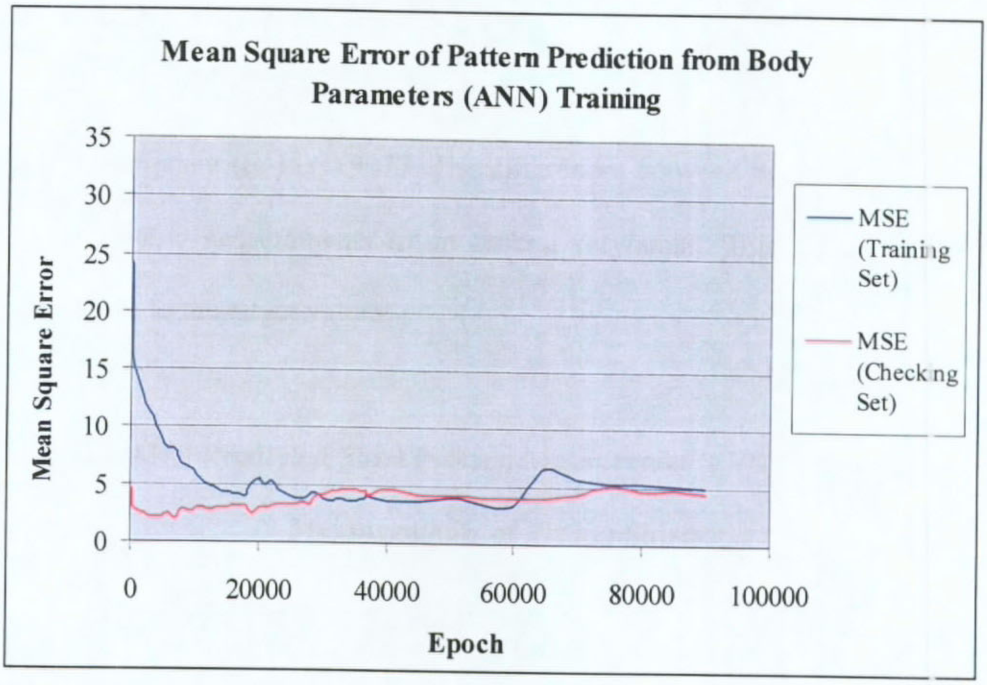
According to Fausett (1994), too small and too large of the values for initial weights can affect the performance and accuracy of the model. The common procedure is to initialize the weights to random values between -0.5 and 0.5. The training program in this study was also set at this interval.

6.4.5 Condition for Termination of ANN Program Training

The training program may terminate at the very beginning of the training due to the fluctuation of the mean square error of training pairs. The real minimal error may not be reached. In order to avoid the termination of training prematurely, a condition of intervention was set. Training will not stop unless the mean square error, i.e. the error between the training data and target data of each epoch, was below a pre-set value. After the mean square error was below the pre-set value, training stopped when both the mean square errors of training pairs and checking pairs are approaching minimum.

Fig. 6.2 plots the mean square errors of the training pairs and checking pairs. As can be seen, the errors generally reduce and then increase with certain fluctuation. It is reasonable to terminate training when the error of training pairs is about 4. At this range, the MSE of training pairs approached minimum and the trend of the MSE of checking pairs was almost flat. In order to obtain the best model, preliminary computations with training terminating at MSE of training pairs equaled at value varying from 3.5 to 4.5 with a step of 0.1 was performed. It was found that training terminated when the MSE of training pairs equals 4.3 resulted in the best prediction model with least prediction errors.

Fig. 6.2 The Mean Square Error of Pattern Prediction from Body Parameters in ANN Training



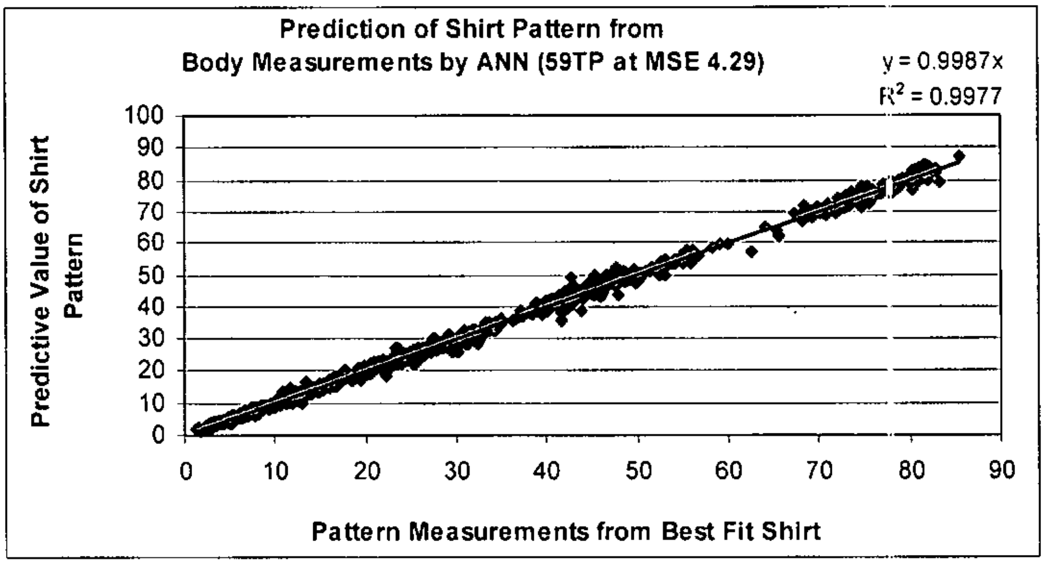
6.4.6 Application of ANN Program

In this application program in C language, two files were needed. The first one was the "weight.dat" from the training program. Second was the scaled down input data named "input.dat". This input data only contained 34 body parameters. The application would read these two files and applied the activation function for training. The results were shown in a new file named "application.dat". This file contains the predicted pattern parameters.

6.5 Evaluation of Pattern Prediction Using Artificial Neural Network

Fig. 6.3 plots the ANN predicted shirt pattern measurements against the shirt pattern measurements of the actual fitting shirts for 59 pairs of data. As can be seen, the squared correlation coefficient (R^2) is 0.9977. The differences between the predicted and actual fitting shirt pattern measurements are in general very small. This means that predicted results are close to the target values.

Fig. 6.3 ANN Predicted Shirt Pattern Measurements VS Actual Pattern Measurements of Fitting Shirts



6.6 The Deviation of ANN Predicted Shirt Pattern Measurements

In order to further evaluate the shirt pattern prediction model based ANN, the deviation of each pattern parameter must be considered. The mean errors and the range of errors in terms of 95% confidence interval are listed in Table 6.2. As can be seen, the prediction for most pattern parameters has very low percentage of error based on 95% confidence limit. In the critical fitting areas of shirt patterns such as collar girth, chest girth, waist girth, hip girths and shoulder width, the prediction is very good.

Pattern parameters G_{11} (8-26), G_{12} (8-9) and G_{22} (curve 9-26) are important for the front neck girth. G_{11} is front neck width, G_{12} is front neck depth and G_{22} is front neck girth. For G_{11}, the standard deviation is 0.21 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 6.75%. For G_{12}, the standard deviation is 0.24 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be –9.01%. For G_{22}, the standard deviation is 0.26 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 6.11%.

Pattern parameters G_5 (0-19), G_6 (0-1) and G_{27} (curve 1-19) are important for the back neck girth of shirt pattern. G_5 is the back neck width, G_6 is back neck depth and G_{27} is the back neck girth. For G_5, the standard deviation is 0.21 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 4.96%. For G_6, the standard deviation is 0.10 cm; the mean error is -0.01 cm and the maximum deviation based on 95% confident limit can be –3.68%. For G_{27}, the standard deviation is 0.22 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 3.99%.

Pattern parameters G_9 (3-15) and G_{19} (10-15) constitute the chest girth of shirt pattern. G_9 is the back chest girth and G_{19} is front chest girth. For G_9, the standard deviation is 0.46 cm; the mean error is 0.02 cm and the maximum deviation based on 95% confident limit can be 3.37%. For G_{19}, the standard deviation is 0.47 cm; the mean error is 0.02 cm and the maximum deviation based on 95% confident limit can be 3.46%.

Pattern parameters G_{31} (4-37) and G_{30} (11-38) constitute the waist girth of shirt pattern. G_{31} is the back waist girth and G_{30} is front waist girth. For G_{31}, the standard deviation is 1.00 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 8.04%. For G_{30}, the standard deviation is 0.99 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 7.94%.

G_{21} (5-39) and G_{20} (12-40) are the pattern parameters of the hip girth of shirt pattern. G_{21} is the back hip girth and G_{20} is front hip girth. For G_{21}, the standard deviation is 0.60 cm; the mean error is 0.03 cm and the maximum deviation based on 95% confident limit can be 4.38%. For G_{20}, the standard deviation is 0.60 cm; the mean error is 0.03 cm and the maximum deviation based on 95% confident limit can be 4.42%.

Pattern parameter G_1 (1-3) is the length between shoulder and underarm level. The accuracy of this measurement will directly affect the fitting on armhole and the comfort of wearer when they move their arms. The standard deviation is 0.45 cm; the mean error is 0.03 cm and the maximum deviation based on 95% confident limit can be 3.11%.

Pattern parameter G_{13} (26-29) is the shoulder width of shirt pattern. The accuracy of this measurement will affect the subjective feeling on wearer when they move their arms. Besides, this is an important fitting area that affects the overall fitting,. The standard deviation is 0.46 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 5.60%.

It can be seen from the table that the maximum percentage of error of 4 pattern predictions exceeds 10%. These pattern parameters are G_{10} (7-8), G_{15} (17-18), G_{18} (12-13) and G_{33} (23-24). These parameters are not so critical to fitting, but only affecting the style of shirt. G_{10} is the difference between front panel and back panel. G_{15} is the length between back hip and bottom of shirt. G_{18} is the length between front hip and bottom of shirt. G_{33} is the dart width between yoke panel and back panel at armhole level.

Table 6.2 Deviation of Pattern Prediction from ANN Model

with 59 Sets of Training Data

Pattern Parameters	Deviation of Pattern Parameters from ANN				
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)
G_1	29.21	0.45	0.03	-0.84~0.91	-2.39~3.11
G_2	47.63	1.05	0.02	-2.05~2.08	-4.31~4.37
G_3	79.31	1.24	0.02	-2.41~2.44	-3.04~3.08
G_4	54.78	0.92	0.04	-1.77~1.85	-3.23~3.37
G_5	8.36	0.21	0.01	-0.40~0.41	-4.77~4.96
G_6	5.37	0.10	-0.01	-0.20~0.18	-3.68~3.36
G_7	7.58	0.17	-0.01	-0.34~0.32	-4.43~4.24
G_8	23.31	0.44	0.01	-0.86~0.87	-3.68~3.75
G_9	27.35	0.46	0.02	-0.89~0.92	-3.24~3.37
G_{10}	5.73	0.41	-0.01	-0.80~0.78	-14.05~13.70
G_{11}	6.12	0.21	0.00	-0.41~0.41	-6.66~6.75
G_{12}	5.18	0.24	0.00	-0.47~0.46	-9.01~8.84
G_{13}	16.37	0.46	0.01	-0.90~0.92	-5.50~5.60
G_{14}	33.56	0.87	0.02	-1.68~1.73	-5.02~5.16
G_{15}	7.36	0.39	0.01	-0.76~0.78	-10.30~10.58
G_{16}	23.40	0.79	0.02	-1.53~1.56	-6.52~6.66
G_{17}	72.74	1.36	0.03	-2.64~2.69	-3.63~3.70
G_{18}	6.62	0.35	0.01	-0.66~0.69	-10.04~10.41
G_{19}	27.40	0.47	0.02	-0.91~0.95	-3.32~3.46
G_{20}	27.35	0.60	0.03	-1.15~1.21	-4.20~4.42
G_{21}	27.26	0.60	0.03	-1.14~1.20	-4.19~4.38
G_{22}	8.51	0.26	0.00	-0.51~0.52	-6.04~6.11
G_{23}	20.91	1.02	-0.01	-2.00~1.99	-9.58~9.50
G_{24}	13.36	0.54	-0.02	-1.07~1.03	-8.04~7.68
G_{25}	15.31	0.75	0.00	-1.47~1.48	-9.61~9.64
G_{26}	24.46	0.43	0.01	-0.84~0.86	-3.43~3.52
G_{27}	11.15	0.22	0.01	-0.43~0.44	-3.88~3.99
G_{28}	12.49	0.61	-0.01	-1.19~1.18	-9.56~9.45
G_{29}	43.70	1.30	-0.01	-2.55~2.54	-5.84~5.81
G_{30}	24.50	0.99	0.01	-1.92~1.95	-7.85~7.94
G_{31}	24.45	1.00	0.01	-1.94~1.97	-7.94~8.04
G_{32}	33.87	1.50	0.02	-2.92~2.97	-8.62~8.76
G_{33}	1.93	0.31	0.00	-0.61~0.60	-31.46~31.21

Note:
a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error +1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

6.7 Comparison of Prediction Errors of ANN Model, MLR Equations and Tailoring Experts' Formulae

Table 6.3 shows the comparison between the pattern predictions from ANN model, MLR equations and 4 tailoring experts' formulae in terms of percentage error based on 95% confidence interval.

It can be seen, the prediction errors of the ANN model is significantly smaller in all pattern parameters than those of the four tailoring experts' formulae and in MRL equations. In most cases, the maximum percentages of errors from ANN model are less than 10%. Although some of the maximum percentages of errors from MRL equations are also less than 10%, the accuracy of shirt pattern prediction has been improved by ANN model. Besides, the errors of those 4 tailoring expert's formulae often exceed 20%. Such tailoring experts' drafting formulae obviously cannot produce patterns to fit the diverse body shapes. Moreover, the pattern prediction of ANN model is also better than that of multiple linear equations. It can be believed that the non-linear model based on ANN can better model the complex nonlinear relationship between body measurements and pattern parameters.

Table 6.3 Comparison of Percentage Error Based on 95% Confident Limit between Pattern Prediction from ANN Model and Calculated Results from 4 Tailoring Experts

Pattern Parameters	Percentage Error in 95% Confident Interval (%)					
	ANN	MLR	Aldrich	Cham	Tailor A	Tailor B
G1	-2.89~3.11	-6.82~6.71	13.24~32.50	-3.36~26.72	0.06~30.14	8.62~38.70
G2	-4.31~4.37	-4.81~11.91	-10.96~26.23	-14.11~23.08	-4.66~32.53	-4.66~32.53
G4	-3.23~3.37	-4.23~4.18	-10.61~3.98	-3.31~11.29	-35.68~-4.51	11.30~25.89
G5	-4.77~4.96	-7.70~7.70	9.31~29.41	10.33~27.60	9.03~27.49	-11.01~9.08
G6	-3.68~3.36	-6.21~6.24	4.70~27.74	18.34~50.28	-6.47~16.57	-23.23~-0.19
G7	-4.43~4.24	-5.89~27.71	-2.64~30.98	-37.33~11.07	-33.95~-0.89	-22.07~10.98
G8	-3.68~3.75	-4.73~4.88	-2.43~13.65	-4.73~26.29	-7.15~8.93	-2.11~21.58
G9	-3.24~3.37	-4.19~4.07	-12.41~1.81	-3.27~10.95	-12.05~2.18	11.35~25.58
G10	-14.05~13.70	-19.93~61.89	-30.39~73.32	-37.82~65.25	-40.87~62.85	-23.41~80.30
G11	-6.66~6.75	-8.73~8.73	-11.09~7.01	-19.94~-1.55	-37.02~-16.15	24.85~42.96
G12	-9.01~8.84	-35.72~9.43	-44.13~4.13	-56.55~-3.51	-51.08~-1.18	-1.31~46.00
G13	-5.50~5.60	-8.54~8.63	-10.46~12.98	-24.21~23.72	-51.58~-17.23	-50.92~-14.06
G16	-6.52~6.66	-8.71~8.54	8.21~37.72	14.55~46.16	10.11~32.35	6.43~38.04
G19	-3.32~3.46	-4.25~4.28	-8.42~5.52	-2.94~10.99	4.72~18.66	11.66~25.59
G20	-4.20~4.42	-6.32~6.11	-6.98~11.00	-5.15~12.82	-14.99~-0.95	9.47~27.45
G21	-4.19~4.38	-6.61~6.52	-11.05~7.08	-5.55~12.59	-15.76~-0.88	9.13~27.26
G23	-9.58~9.50	-12.52~12.54	23.44~56.37	43.85~71.71	2.03~35.29	35.23~65.04
G26	-3.43~3.52	-5.76~5.75	-0.63~14.55	-5.05~26.78	-25.14~-2.85	0.68~21.52
G28	-9.56~9.45	-12.73~12.16	-56.21~-8.01	-31.87~17.58	-9.33~30.37	-30.70~6.55
G29	-5.84~5.81	-3.26~11.34	-63.12~-44.50	-63.12~-44.50	-49.39~-30.77	-49.39~-30.77
G30	-7.85~7.94	-9.39~9.18	-17.49~6.92	-13.41~11.00	-19.13~5.29	4.95~29.37
G31	-7.94~8.04	-9.40~9.68	-21.79~2.60	-13.61~10.78	-19.33~5.06	4.79~29.19
G32	-8.62~8.76	-5.76~15.33	-12.00~23.36	-12.07~23.17	-13.16~22.20	-3.61~31.75
G33	-31.46~31.21	-47.64~46.70	11.20~126.48	0.81~116.09	-11.66~103.63	0.81~116.09

Note: % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

6.8 Conclusions

Although the MLR equations established in the previous Chapter clarifies the underlying relationship between the shirt pattern and body measurements, provides improved prediction of shirt pattern in comparison with the traditional tailoring expert's formulae, the prediction is still not sufficiently accurate due to the fact that they cannot model the possibly complex non-linear relationship. Therefore, in this Chapter, Artificial Neural Network was applied for establishing the relationship between shirt pattern parameters and body measurements.

Results presented in this Chapter demonstrated that ANN is effective in modeling the non-linear relationship between shirt pattern parameters and body measurements. It was found that the shirt pattern parameters predicted by ANN model are accurate. The errors of important pattern parameters, based on 95% confidence interval, are less than 10%. Compared with the errors of the tailoring experts' formulae, there is a significant reduction in the prediction error.

The ANN model is proven to be an effective method for shirt pattern drafting to achieve individual fit and useful for the implementation on mass customization.

Chapter 7

Prediction of Subjective Fitting Perception from Shirt Pattern Parameters and Body Measurements

Chapter 7

Prediction of Subjective Fitting Perception from Shirt Pattern Parameters and Body Measurements

7.1 Introduction

The previous Chapter showed that Artificial Neural Network is effective in predicting the shirt pattern parameters from body measurements for making a fitting shirt for a target customer. An alternative question is that, assuming a pattern has been drafted for a customer, what the level of fitting is. This would help the customer to decide on whether he is pleased with the degree of fitting. In order to answer this question, it is necessary to establish the relationship between the fitting perception and pattern parameters and body measurements.

This Chapter reports on the application of ANN to establish a model for predicting the fitting perception from the pattern parameters and body measurements. The model can be used by designers to evaluate shirt fitting when designing the shirt pattern before an actual garment sample needs to be made.

7.2 Nomenclature

B'	= Converted value of each body parameter
B	= Original value of each body measurement
B_{min}	= Minimum value of each body measurement
B_{max}	= Maximum value of each body measurement
G'	= Converted value of each pattern parameter / Predicted value of each pattern parameter
G	= Original value of each pattern measurement
G_{min}	= Minimum value of each pattern measurement
G_{max}	= Maximum value of each pattern measurement
SR'	= Converted value of each subjective rating
SR	= Original value of each Subjective rating
SR_{min}	= Minimum value of subjective rating at each subject
SR_{max}	= Maximum value of subjective rating at each subject

7.3 Subjective Fitting Perception

7.3.1 Subjective Rating

Each human subject was asked to wear 10 shirt samples including his best-fit shirt for assessing the fitting perception with respect to garment size variation. The detailed procedure and rating questionnaire were explained in Chapter 3. The total number of wearer trials was 559 because some subjects could not have enough large shirt samples for evaluation.

The subjects were required to follow the rating procedure to assess the shirt fitting feeling in critical areas. After doing some motions by subjects such as uplifting and bending forward of both hands, subjects were required to fill in twelve questions about the tightness and looseness feeling on each wear trial. The ratings were focused on neckline, bodice, armhole and sleeve length in terms of static and dynamic conditions. The subjective rating has a scale from 1 to 5, 1 being very tight and 5 being very loose.

In addition to the wearer himself, two tailors and two designers were invited to assess shirt fitting. The averages of the ratings from the wearer, two tailors and two designers were used for further analysis. The results of subjective ratings are listed in Appendix III. The minimum and maximum standard deviation of all subjective rating was ranged from 0.00 to 0.74 respectively. The standard deviation of all subjective evaluations was listed in Appendix IV.

7.4 Development of ANN Model for the Prediction of Fitting Perception

7.4.1 Architecture and Training Algorithm of the Model

The basic architecture and training algorithm are the same as reported in Chapter 6. The differences are the number of input units, hidden units, output units, training pairs and checking pairs. Table 7.1 lists the ANN model parameters for modeling the prediction of fitting perception. The computational program was adjusted in accordance with the new parameters.

Table 7.1 Parameters of the ANN Model for the Prediction of Fitting Perception

Activation function at output layer	$f(x)=\frac{1}{1+e^{-x}}$
Activation function at hidden layer	$f(x)=\frac{1}{1+e^{-x}}$
Input parameters	34 body parameters + 33 shirt pattern parameter
Output parameters	12 Subjective parameters
Number of hidden units	80
Number of training pairs	509
Number of cross-checking pairs	50

7.4.2 Input, Output and Hidden Units

In this prediction model, the input units are shirt pattern parameters (G) and body parameters (B). The output units are subjective fitting perceptions (P). The current network has sixty-seven inputs units and twelve output units.

In this model, a large number of computational experiments have also been conducted for investigating the appropriate number of hidden units and it was found that 80 hidden units were adequate for the model training.

7.4.2.1 Conversion of Input and Output Units

Three sets of data, shirt pattern parameters (G), body parameters (B) and subjective fitting perception (P) were also scaled down to be within (0,1) to avoid the overfloat problem in computation. Output data were also scaled down to be within (0,1) to correspond to the output range of the binary sigmoid activation function. Four equations were used in this model.

For body parameters:

$$B' = \frac{B - B_{\min}}{B_{\max} - B_{\min}} \times 0.8 + 0.1 \qquad (7.1)$$

where,

B' = Converted value of each body parameter

B = Original value of each body measurement

B_{min} = Minimum value of each body measurement

B_{max} = Maximum value of each body measurement

For pattern parameters:

$$G' = \frac{G - G_{min}}{G_{max} - G_{min}} \times 0.8 + 0.1 \qquad (7.2)$$

where,

G' = Converted value of each pattern parameter

G = Original value of each pattern measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

For subjective fitting perception:

$$SR' = \frac{SR - SR_{min}}{SR_{max} - SR_{min}} \times 0.8 + 0.1 \qquad (7.3)$$

where,

SR' = Converted value of each subjective rating

SR = Original value of each Subjective rating

SR_{min} = Minimum value of subjective rating at each subject

SR_{max} = Maximum value of subjective rating at each subject

For converting the scaled down outputs back to original scale:

$$G = [\frac{(G'-0.1)}{0.8} \times (G_{max} - G_{min})] + G_{min} \quad (7.4)$$

where,

G' = Predicted value of each pattern parameter

G = Pattern value in normal measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

The scaled data was then written into a data file format, named "input.dat" for program training. The sequence of the data in this file was that the 34 body parameters, 33 pattern parameters and 12 subjective fitting ratings were listed from left to right for each case. From top to bottom, it was the number of training sets. In this case, the training sets of data were 509 out of 559 subjects. The remaining of 50 sets of data was used as the cross-validation set (checking pairs).

7.4.3 Training Set and Cross-checking Set for ANN Training

According to Hecht-Nielsen (1990), two sets of data for ANN program training were required for obtaining an optimum prediction model. In this application, 50 data pairs, representing approximately 10% of the total data pairs, were used as cross-checking set and the remaining 509 data pairs were used as training set. These two data sets were written into separated data files. The former was kept in the "checking.dat", which consisted of 67 input parameters and 12 output parameters from left to right and 50 set of data from top to bottom. The latter was stored in the "input.dat", which also consisted same number of input and output parameters but the there were 509 sets of data from top to bottom in the file.

7.4.4 Learning Rate

Too high in learning rate would cause too long training time, too fast learning rate would result in a premature model. Computational experiments were carried to determine the appropriate learning rate for this application. A rate of 0.1 was found to be adequate for this application.

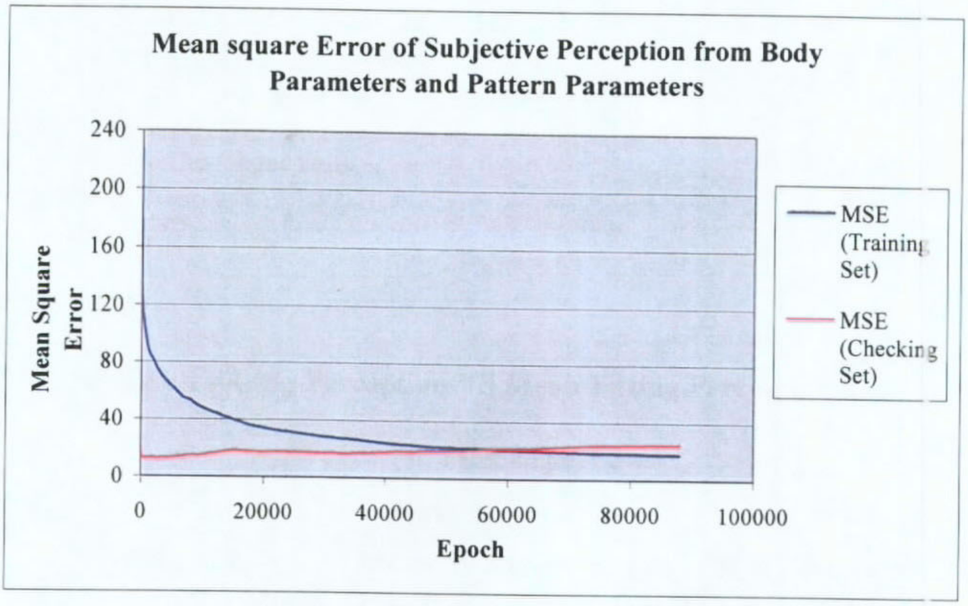
7.4.5 Initialization of Weights

The initial weights of the training program were set to random values between -0.5 and 0.5. According to Fausett (1994), this is an appropriate range.

7.4.6 Condition for Termination of ANN Program Training

According to Hecht-Nielsen (1990), it is not necessarily advantageous to continue training until the total squared error actually reaches the minimum. Training should terminate when a generalized model has been achieved. The condition for the termination of training is determined according to the mean square errors of the training pairs and checking pairs. The general rule is that both mean square errors of the training pairs and checking pairs should approach minimum. Fig. 7.1 plots the trends of the mean square errors with respect to epochs. As can be seen, when the MSE of training pairs is about 25, the changes of the MSE of checking pairs are very small (with very slow increase), and the MSE of training pairs will only reduce slowly with further training. This means that when MSE of training pairs is about 25, a generalized mapping of inputs and outputs may be achieved. In order to obtain the best model, training was terminated when the MSE of training pairs equaled to a value from 20.0 to 30.0 with a step of 0.2. The resulting models were compared in terms of prediction accuracy for the training pairs and checking pairs. It was found that the prediction model derived when the MSE of training pairs is 22.0 had least prediction errors. This model was therefore used for further analysis.

Fig. 7.1 The Mean Square Error of Subjective Perception Prediction from Body Parameters and Pattern Parameters by ANN Model



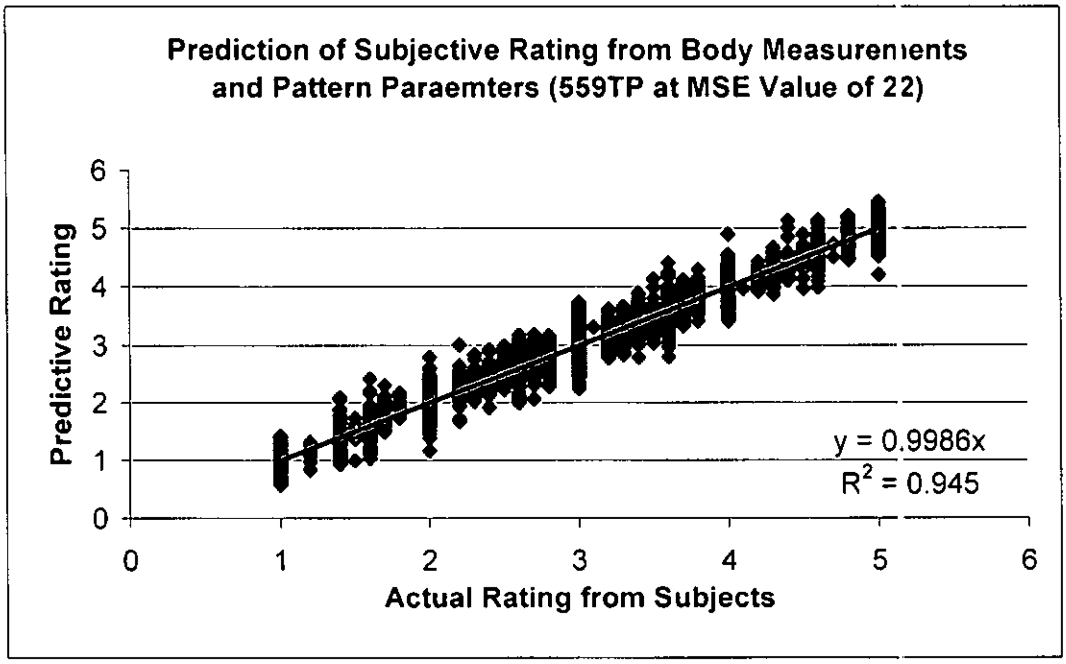
7.4.7 Application of ANN Model

With the weights of the ANN, the model can now be applied for predicting the fitting perception. The application program of the ANN model requires two input files. The first one was the "weight.dat" from training, the second one was the scaled down input data named "input.dat". This input data contained 34 body parameters and 33 pattern parameters. The application would read these two files and applied the activation function for application. The results were shown in a new file named "application.dat".

7.5 Evaluation of the ANN Model for Predicting Fitting Perception

Fig. 7.2 plots the fitting perception predicted from ANN model against the mean fitting perception rated by the wearer and the expert panel for the 559 cases. As can be seen, the prediction is generally accurate with a percentage of fit (R^2) of 0.945. The predicted values are close to the target values.

Fig. 7.2 Predicted Fitting Perception VS Mean Fitting Perception Rated by the Wearer and the Expert Panel



7.6 The Deviation of the Prediction of Fitting Perception

In order to further evaluate the accuracy of the prediction model, it is necessary to consider the magnitude of the deviation of the predicted fitting perception from the mean fitting perception rated by the wearer and the panel. The mean value, standard deviation, minimum value and maximum value of the prediction error for each fitting perception parameter are listed in Table 7.2.

In the table, SR_1 represents the tightness feeling at the neck when the wearer is standing still. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.84 from ANN prediction model.

SR_2 is the tightness feeling at the neck when the wearers were required to move their head to feel the tightness of shirt neck. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.68 from the ANN prediction model.

SR_3 is the fit of shirt shoulder. Subjects were required to rate the fit of the shirt shoulder from their point of view. The mean error is 0.00. The standard deviation is 0.11, the minimum deviation is 0.00 and the maximum deviation is 0.65 from the ANN prediction model.

SR_4 is the tightness feeling on shirt armhole at static condition. The mean error is 0.00. The standard deviation is 0.10, the minimum deviation is 0.00 and the maximum deviation is 0.57 from the ANN prediction model.

SR_5 is the tightness feeling on shirt armhole when the wearers were required to uplift their hands for rating. The mean error is 0.00. The standard deviation is 0.11, the minimum deviation is 0.00 and the maximum deviation is 0.81 from the ANN prediction model.

SR_6 is the tightness feeling on shirt armhole when the wearers were required to bend their hands forward for rating. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.81 from the ANN prediction model.

SR_7 is the tightness feeling on shirt front panel when the wearers are standing still. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.89 from the ANN prediction model.

SR_8 is the tightness feeling on shirt front panel when the wearers were required to uplift their hands for rating. The mean error is 0.00. The standard deviation is 0.10, the minimum deviation is 0.00 and the maximum deviation is 0.80 from the ANN prediction model.

SR_9 is the tightness feeling on shirt front panel when the wearers were required to bend their hands forward for rating. The mean error is 0.00. The standard deviation is 0.10, the minimum deviation is 0.00 and the maximum deviation is 0.79 from the ANN prediction model.

SR_{10} is the fitting on sleeve length. The mean error is 0.00. The standard deviation is 0.14, the minimum deviation is 0.00 and the maximum deviation is 0.80 from the ANN prediction model.

SR_{11} is the tightness feeling on shirt back panel when the wearers were required to uplift their hands for rating. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.80 from the ANN prediction model.

SR_{12} is the tightness feeling on shirt back panel when the wearers were required to bend their hands forward for rating. The mean error is 0.00. The standard deviation is 0.12, the minimum deviation is 0.00 and the maximum deviation is 0.65 from the ANN prediction model.

Therefore, the prediction of fitting perception using the ANN model is generally accurate with the maximum deviations less than 0.9, which is even smaller than the possible error a human observer can have in rating the fitting perception.

Table 7.2 The Deviation of Subjective Rating Prediction from ANN Model

Subjective Perception Parameters	Deviation of Subjective Rating from Prediction ANN Model			
	Mean Error	SD	Min	Max
SR_1	0.00	0.12	0.00	0.84
SR_2	0.00	0.12	0.00	0.68
SR_3	0.00	0.11	0.00	0.65
SR_4	0.00	0.10	0.00	0.57
SR_5	0.00	0.11	0.00	0.81
SR_6	0.00	0.12	0.00	0.81
SR_7	0.00	0.12	0.00	0.89
SR_8	0.00	0.10	0.00	0.80
SR_9	0.00	0.10	0.00	0.79
SR_{10}	0.00	0.14	0.00	0.80
SR_{11}	0.00	0.12	0.00	0.80
SR_{12}	0.00	0.12	0.00	0.65

7.7 Conclusions

A model for the prediction of the fitting perception of men's shirts has been established using Artificial Neural Network. The prediction has been shown to be very accurate. The model can be used by the pattern designers to evaluate the pattern in terms of fitting to the target customer before an actual garment sample needs to be produced.

Chapter 8

Prediction of Shirt Patterns from Fitting Requirements and 3D Body Measurements

Chapter 8

Prediction of Shirt Patterns from Fitting Requirements and 3D Body Measurements

8.1 Introduction

The previous Chapters showed that Artificial Neural Network models provide very good prediction of shirt patterns from 3D body measurements and fitting perceptions from 3D body measurements and pattern parameters. They are useful for drafting fitting shirt patterns and evaluating designed shirt patterns, respectively. However, in some cases, customers may like to specify fitting requirements in the shirts they want. Under such circumstances, it is required to predict shirt patterns from fitting requirements and body measurements.

In this Chapter, Artificial Neural Network is applied to establish a model for predicting men's shirt patterns from fitting requirements and body measurements. The model parameters, training process and the accuracy of the prediction model are reported here.

8.2 Nomenclature

B'	= Converted value of each body parameter
B	= Original value of each body measurement
B_{min}	= Minimum value of each body measurement
B_{max}	= Maximum value of each body measurement
G'	= Converted value of each pattern parameter / Predicted value of each pattern parameter
G	= Original value of each pattern measurement
G_{min}	= Minimum value of each pattern measurement
G_{max}	= Maximum value of each pattern measurement
SR'	= Converted value of each subjective rating
SR	= Original value of each Subjective rating
SR_{min}	= Minimum value of subjective rating at each subject
SR_{max}	= Maximum value of subjective rating at each subject

8.3 ANN for Pattern Prediction from Body Measurements and Fitting Requirements

8.3.1 Architecture and Training Algorithm of the Model

In this pattern prediction model, the backpropagation neural network was applied for model building. The input parameters were 34 body parameters and 12 fitting parameters (Ratings of fitting perception). The output parameters were 33 pattern parameters. The number of training pairs was 509. The number of cross-checking pairs was 50 and the number of hidden units was 80. The model parameters are summarized in Table 8.1

Table 8.1 Parameters of ANN Model for Pattern Prediction from Body Measurements and Fitting Requirements

Activation function at output layer	$f(x)=\frac{1}{1+e^{-x}}$
Activation function at hidden layer	$f(x)=\frac{1}{1+e^{-x}}$
Input parameters	34 body parameters + 12 Subjective parameters
Output parameters	33 shirt pattern parameter
Number of hidden units	80
Number of training pairs	509
Number of cross-checking pairs	50

8.3.2 Input, Output and Hidden Units

In this pattern prediction model, the input units were body parameters (B) and fitting perception (P). The output units are shirt pattern parameters (G). The current network has forty-six inputs units and thirty-three output units.

As discussed in Chapter 6 and 7, the number of hidden units is determined by trials and error. It was found that 80 hidden units were adequate for the program training.

8.3.2.1 Conversion of Input and Output Units

Three sets of data, shirt pattern parameters (G), body parameters (B) and fitting perception (P) were scaled down for ANN program training and program application between 0 to 1 to avoid the overfloat problem in computation and also for corresponding to achieve binary sigmoid activation function.

For body parameters:

$$B' = \frac{B - B_{min}}{B_{max} - B_{min}} \times 0.8 + 0.1 \qquad (8.1)$$

where,

B' = Converted value of each body parameter

B = Original value of each body measurement

B_{min} = Minimum value of each body measurement

B_{max} = Maximum value of each body measurement

For pattern parameters:

$$G' = \frac{G - G_{min}}{G_{max} - G_{min}} \times 0.8 + 0.1 \qquad (8.2)$$

where,

G' = Converted value of each pattern parameter

G = Original value of each pattern measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

For subjective rating:

$$SR' = \frac{SR - SR_{min}}{SR_{max} - SR_{min}} \times 0.8 + 0.1 \qquad (8.3)$$

where,

SR' = Converted value of each subjective rating

SR = Original value of each Subjective rating

SR_{min} = Minimum value of subjective rating at each subject

SR_{max} = Maximum value of subjective rating at each subject

For converting back the results to original scale:

$$G = [\frac{(G'-0.1)}{0.8} \times (G_{max} - G_{min})] + G_{min} \qquad (8.4)$$

where,

G' = Predicted value of each pattern parameter

G = Pattern value in normal measurement

G_{min} = Minimum value of each pattern measurement

G_{max} = Maximum value of each pattern measurement

The scaled data was written into a data file format, named "input.dat" for program training. The sequence of the data in this file was that the 34 body parameters, 12 subjective rating and 33 pattern parameters respectively were listed from left to right for each case. From top to bottom, it was the number of training data pairs. In this case, the training set of data had 509 out of 559 data pairs. The rest of 50 sets of data were used as the cross-validation set.

8.3.3 Training Set and Cross-checking Set for ANN Program Training

According to Hecht-Nielsen (1990), two sets of data for ANN program training were required for obtaining an optimum prediction model. In this application, 50 data pairs, representing approximately 10% of the total data pairs, were used as cross-checking set and the remaining 509 data pairs were used as training set. These two data sets were written into separated data files. The former was kept in the "checking.dat", which consisted of 46 input parameters and 33 output parameters from left to right and 50 set of data from top to bottom. The latter was stored in the "input.dat", which also consisted same number of input and output parameters but the there were 509 sets of data from top to bottom in the file.

8.3.4 Learning Rate

As same as Chapter 6 and 7, too high in learning rate would cause too long training time, too fast learning rate would result in a premature model. Preliminary computational experiments were carried to determine the appropriate learning rate for this application. A rate of 0.1 was found to be adequate for this application.

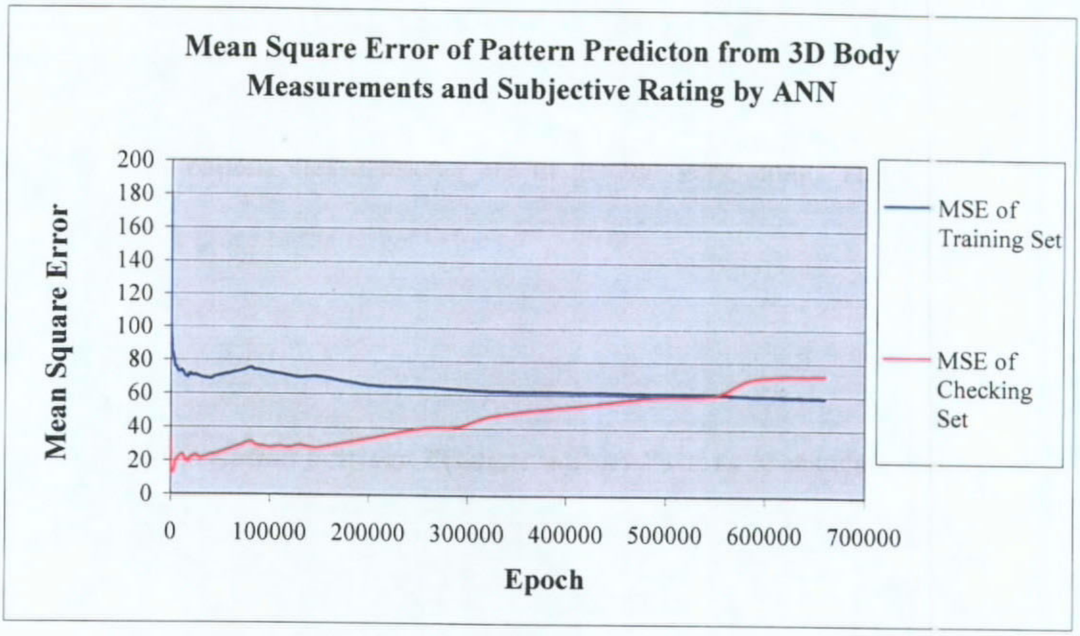
8.3.5 Initial Weights

According to Fausett (1994), an appropriate range of the initial weights of the training program was set to random values between -0.5 and 0.5.

8.3.6 Condition for Termination of ANN Program Training

The general rule for termination of ANN training should be that both mean square errors of the training pairs and checking pairs should approach minimum. Fig. 8.1 plots the trends of the mean square errors against epochs. As can be seen, the MSE of training pairs generally reduces, but the MSE of checking pairs generally increases. It is not appropriate to terminate the training when the MSE of checking pairs is minimum as this would result a very high MSE of training pairs. As can be seen from Fig. 8.1, when the MSE of training pairs reduced to about 65, further training would only reduce the MSE of training pairs very slowly, but increase the MSE of training pairs significantly. It is therefore reasonable to terminate training when the MSE of training pairs is about 65. In order to fine tune the condition for termination of training, training was terminated when the MSE of training pairs equaled to a value varying from 60.0 to 68.0 with a step of 0.2. It was found that the prediction model derived when the MSE of training pairs is 61.8 had least prediction errors. This model was therefore used for further analysis.

Fig. 8.1 The Mean Square Error of Pattern Prediction from 3D Body Measurements and Fitting perception by ANN Model



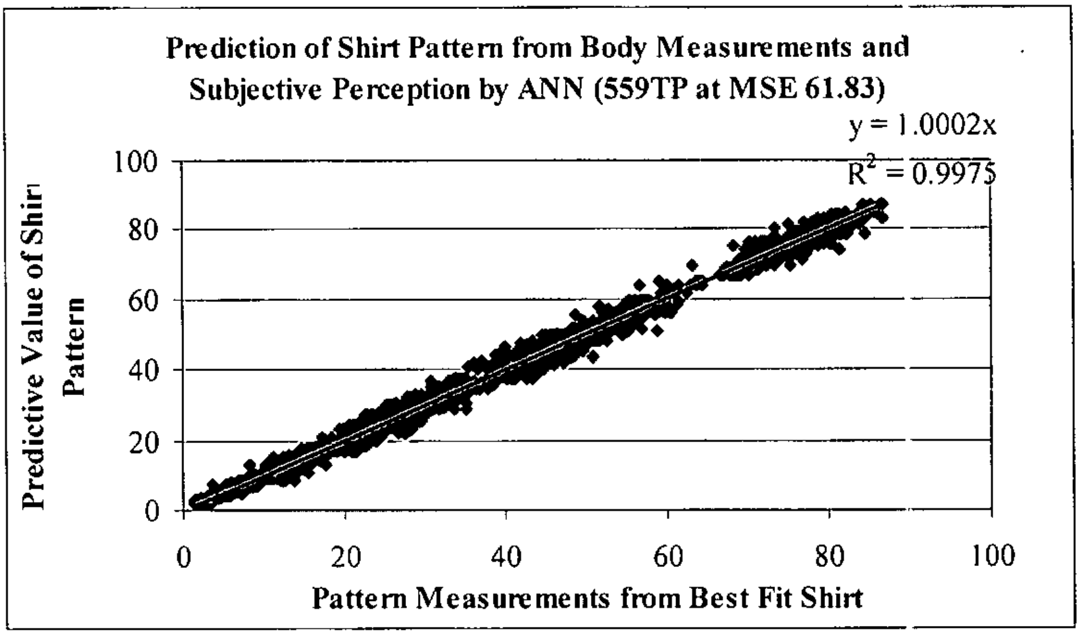
8.3.7 Application of ANN Model

With the weights of the ANN, the model can now be applied for predicting the pattern parameters. The application program of the ANN model requires two input files. The first one was the "weight.dat" from training, the second one was the scaled down input data named "input.dat". This input data contained 34 body parameters and 12 subjective rating parameters. The application would read these two files and applied the activation function for application. The results were shown in a new file named "application.dat".

8.4 Evaluation of Pattern Prediction Using Artificial Neural Network

Fig. 8.2 plots the ANN predicted shirt pattern measurements against the shirt pattern measurements of the actual fitting shirts for 559 pairs of data. As can be seen, the squared correlation coefficient (R^2) is 0.9975. The differences between the predicted and actual fitting shirt pattern measurements are in general very small. This means that predicted results are close to the target values.

Fig. 8.2 The Correlation between Predictive Shirt Pattern Measurements and Actual Pattern Measurements from 559 Training Pairs at MSE Level of 61.83



8.5 The Deviation of ANN Predicted Shirt Pattern Measurements

In order to further evaluate the shirt pattern prediction model based ANN, the deviation of each pattern parameter must be considered. The mean errors and the range of errors in terms of 95% confidence interval are listed in Table 8.2. As can be seen, the prediction for most pattern parameters has very low percentage of error based on 95% confidence limit. In the critical fitting areas of shirt patterns such as collar girth, chest girth, waist girth, hip girths and shoulder width, the prediction is very good.

Pattern parameters of G_{11} (8-26), G_{12} (8-9) and G_{22} (curve 9-26) are important for the front neck girth. G_{11} is front neck width, G_{12} is front neck depth and G_{22} is front neck girth. For G_{11}, the standard deviation is 0.21 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 6.72%. For G_{12}, the standard deviation is 0.37 cm; the mean error is -0.01 cm and the maximum deviation based on 95% confident limit can be –14.14%. For G_{22}, the standard deviation is 0.32 cm; the mean error is 0.01 cm and the maximum deviation based on 95% confident limit can be 7.37%.

Pattern parameters G_5 (0-19), G_6 (0-1) and G_{27} (curve 1-19) are important for the back neck girth of shirt pattern. G_5 is the back neck width, G_6 is back neck depth and G_{27} is the back neck girth. For G_5, the standard deviation is 0.21 cm; the mean error is -0.01 cm and the maximum deviation based on 95% confident limit can be 4.91%. For G_6, the standard deviation is 0.14 cm; the mean error is -0.01 cm and the maximum deviation based on 95% confident limit can be –5.368%. For G_{27}, the standard deviation is 0.24

cm; the mean error is -0.02 cm and the maximum deviation based on 95% confident limit can be 4.33%.

Pattern parameters G_9 (3-15) and G_{19} (10-15) constitute the chest girth of shirt pattern. G_9 is the back chest girth and G_{19} is front chest girth. For G_9, the standard deviation is 0.72 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 5.18%. For G_{19}, the standard deviation is 0.71 cm; the mean error is 0.02 cm and the maximum deviation based on 95% confident limit can be 5.18%.

Pattern parameters G_{31} (4-37) and G_{30} (11-38) constitute the waist girth of shirt pattern. G_{31} is the back waist girth and G_{30} is front waist girth. For G_{31}, the standard deviation is 1.03 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 8.27%. For G_{30}, the standard deviation is 1.01 cm; the mean error is -0.02 cm and the maximum deviation based on 95% confident limit can be -8.17%.

G_{21} (5-39) and G_{20} (12-40) are the pattern parameters of the hip girth of shirt pattern. G_{21} is the back hip girth and G_{20} is front hip girth. For G_{21}, the standard deviation is 0.74 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 5.33%. For G_{20}, the standard deviation is 0.73 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 5.24%.

Pattern parameter G_1 (1-3) is the length between shoulder to underarm level. The accuracy of this measurement will directly affect the fitting on armhole and the comfort of wearer when they move their arms. The standard deviation is 0.59 cm; the mean error is 0.00 cm and the maximum deviation based on 95% confident limit can be 3.96%.

Pattern parameter G_{13} (26-29) is the shoulder width of shirt pattern. The accuracy of this measurement will affect the subjective feeling on wearer when they move their arms. Besides, this is an important fitting area that affects the overall fitting. The standard deviation is 0.49 cm; the mean error is 0.02 cm and the maximum deviation based on 95% confident limit can be 6.01%.

It can be seen from the table that the maximum percentage of error of 9 pattern predictions exceeds 10%. These pattern parameters are G_{10} (7-8), G_{12} (8-9), G_{15} (17-18), G_{18} (12-13), G_{23} (angle 27,26,29), G_{24} (29-31), G_{25} (24-30), G_{28} (angle 20,19,21) and G_{33} (23-24). Some parameters are not so critical to fitting, but only affecting the style of shirt. G_{10} is the difference between front panel and back panel. G_{15} is the length between back hip and bottom of shirt. G_{18} is the length between front hip and bottom of shirt. G_{24} is the vertical distance for determining the front armhole curve. G_{25} is the vertical distance for determining the back armhole curve. G_{33} is the dart width between yoke panel and back panel at armhole level.

G_{12} is the front neck depth. It does not affect the fitting of neckline due to pattern parameters of neck girth are very accuracy in fitting. Besides pattern parameters G_{23} and

G_{28} are the front shoulder angle and the back shoulder angle respectively. The error exceed 10% is still acceptable due to the deviation within two to three degree at those position could not affect the shirt fitting significantly.

Table 8.2 Deviation of Pattern Prediction from ANN Model with 559 Sets of Training Data

Pattern Parameters	Deviation of Pattern Parameters from ANN				
	Sample Mean (cm)	SD (cm)	Mean Error (cm)	95% Confident Interval (cm)	% Error in 95% Confident Interval (%)
G_1	29.21	0.59	0.00	-1.15~1.16	-3.93~3.96
G_2	47.63	1.18	-0.01	-2.33~2.31	-4.90~4.85
G_3	79.31	1.42	0.09	-2.69~2.88	-3.40~3.63
G_4	54.78	1.42	0.05	-2.72~2.83	-4.97~5.16
G_5	8.36	0.21	-0.01	-0.41~0.40	-4.91~4.79
G_6	5.37	0.14	-0.01	-0.29~0.26	-5.38~4.90
G_7	7.58	0.19	0.00	-0.38~0.37	-4.96~4.93
G_8	23.31	0.52	0.01	-1.00~1.03	-4.29~4.41
G_9	27.35	0.72	0.00	-1.41~1.42	-5.17~5.18
G_{10}	5.73	0.47	-0.01	-0.93~0.92	-16.30~16.01
G_{11}	6.12	0.21	0.01	-0.40~0.41	-6.53~6.72
G_{12}	5.18	0.37	-0.01	-0.73~0.71	-14.14~13.77
G_{13}	16.37	0.49	0.02	-0.95~0.98	-5.83~6.01
G_{14}	33.56	1.28	-0.03	-2.55~2.48	-7.60~7.40
G_{15}	7.36	0.42	0.02	-0.80~0.84	-10.83~11.44
G_{16}	23.40	0.75	0.03	-1.43~1.49	-6.13~6.37
G_{17}	72.74	1.47	0.13	-2.75~3.01	-3.78~4.13
G_{18}	6.62	0.43	0.02	-0.82~0.86	-12.34~12.93
G_{19}	27.40	0.71	0.02	-1.37~1.42	-5.01~5.18
G_{20}	27.35	0.73	0.00	-1.43~1.43	-5.24~5.24
G_{21}	27.26	0.74	0.00	-1.45~1.45	-5.33~5.33
G_{22}	8.51	0.32	0.01	-0.61~0.63	-7.16~7.37
G_{23}	20.91	1.25	-0.08	-2.54~2.38	-12.13~11.37
G_{24}	13.36	0.79	-0.02	-1.57~1.54	-11.76~11.53
G_{25}	15.31	0.87	-0.04	-1.74~1.67	-11.38~10.87
G_{26}	24.46	0.50	0.02	-0.97~1.00	-3.95~4.09
G_{27}	11.15	0.24	-0.02	-0.48~0.45	-4.33~4.05
G_{28}	12.49	0.76	0.00	-1.49~1.48	-11.91~11.88
G_{29}	43.70	1.77	0.09	-3.38~3.56	-7.72~8.16
G_{30}	24.50	1.01	-0.02	-2.00~1.97	-8.17~8.04
G_{31}	24.45	1.03	0.00	-2.02~2.02	-8.25~8.27
G_{32}	33.87	1.29	0.00	-2.52~2.53	-7.45~7.47
G_{33}	1.93	0.40	-0.02	-0.80~0.76	-41.34~39.48

Note:

a) Sample Mean = Summation of actual measurement/no. of samples

b) Mean error = (actual measurement – calculated result) / no. of samples

c) S.D = Standard deviation

d) 95% confident interval = mean error – 1.96*SD < e < mean error +1.96*SD

e) % error in 95% confident interval = [(mean error – 1.96*SD)/mean]*100 < e < [(mean error +1.96*SD)/mean]*100

8.6 Conclusions

The present work showed that the Artificial Neural Network model for pattern prediction from 3D body measurements and fitting perception is effective and accurate. Apart from those pattern parameters affecting the shirt style, the prediction errors of critical pattern parameters are generally less than 8%. Automatic pattern drafting system can be programmed based on the model to draft shirt patterns automatically with the inputs of fitting requirements and body measurements.

Chapter 9

Evaluation of Shirt Patterns Designed Using Developed ANN Model

Chapter 9

Evaluation of Shirt Patterns Designed Using Developed ANN Model

9.1 Introduction

The previous Chapters showed that Artificial Neural Network models provide very good prediction of shirt patterns from 3D body measurements and fitting requirements. They are useful and significant for drafting fitting shirt patterns. In order to further evaluate the accuracy and validity of the model, dress shirts for two wearers were designed and made using their body measurements by applying the Artificial Neural Network model.

In this Chapter, the application of the ANN model in deriving pattern parameters is described, and the assessment of the fitting of the dress shirts designed based on the ANN model is reported.

9.2 Nomenclature

B'	= Converted value of each body parameter
B	= Original value of each body measurement
B_{min}	= Minimum value of each body measurement
B_{max}	= Maximum value of each body measurement
G'	= Converted value of each pattern parameter / Predicted value of each pattern parameter
G	= Original value of each pattern measurement
G_{min}	= Minimum value of each pattern measurement
G_{max}	= Maximum value of each pattern measurement
SR'	= Converted value of each subjective rating
SR	= Original value of each Subjective rating
SR_{min}	= Minimum value of subjective rating at each subject
SR_{max}	= Maximum value of subjective rating at each subject

9.3 Body Parameters

9.3.1 Body Measurements for Two Additional Subjects

Two human subjects (A and B), not included in the group for establishing the pattern prediction models, were invited to participate in this experiment. Their bodies were scanned using the Techmath Laser Scanner. The 34 body measurements of these two human subjects, necessary for the input of the ANN model are listed in Table 9.1.

Table 9.1 Body Measurements (in CM) of Subject A and B from Laser Scanner

Body Parameters	Description	Subject A	Subject B
B_1	Body height	172.8	176.8
B_2	Head height	26.4	24.6
B_3	Distance neck to hip	61.0	61.1
B_4	Neck diameter	12.6	12.3
B_5	Mid neck girth	34.8	36.0
B_6	Side upper torso length	23.2	24.7
B_7	Torso width	33.1	34.3
B_8	Total torso girth	159.8	167.2
B_9	Cross shoulder over neck	38.1	37.3
B_{10}	Cross shoulder	41.3	41.1
B_{11}	1/2 Shoulder width	12.8	12.5
B_{12}	Shoulder angle L (°)	22.0	22.0
B_{13}	Shoulder angle R (°)	27.0	23.0
B_{14}	Cross front width	35.1	34.9
B_{15}	Breast width	35.0	36.4
B_{16}	Neck R to waist over bust	41.1	43.6
B_{17}	Neck front to waist over bust	31.2	31.9
B_{18}	Bust points around neck	67.7	74.8
B_{19}	Bust point to neck	25.8	30.2
B_{20}	Chest band	77.9	89.4
B_{21}	Midriff girth	75.4	85.6
B_{22}	Cross back width	33.2	34.5
B_{23}	Back width	32.0	33.7
B_{24}	Neck to underarm back	16.4	16.4
B_{25}	Back length	41.0	41.8
B_{26}	Back length over shoulder blade	44.8	45.4
B_{27}	Distance armpit-waist	23.1	24.9
B_{28}	Waist to hip back	23.8	21.7
B_{29}	Waist girth	67.5	76.3
B_{30}	Waist to hip	25.8	21.9
B_{31}	Hip girth	89.3	95.3
B_{32}	Arm length to neck back	80.5	81.6
B_{33}	Arm length to neck	74.1	75.5
B_{34}	Arm length	61.2	63.0

9.3.2 Conversion of Input Units (Body Parameters)

The body parameters (B) were scaled down for ANN program application to the values between 0 to 1 so as to avoid the over-float problem in computation and to match the output of the binary sigmoid activation function.

For body parameters:

$$B' = \frac{B - B_{\min}}{B_{\max} - B_{\min}} \times 0.8 + 0.1 \qquad (9.1)$$

where,

B'	= Converted value of each body parameter
B	= Original value of each body measurement
$B_{\min}$	= Minimum value of each body measurement
$B_{\max}$	= Maximum value of each body measurement

The scaled down values of body parameters of subjects A and B using equation 9.1 are listed at Table 9.2.

Table 9.2 Converted Values of Body Parameters

Body Parameters	Description	Subject A	Subject B
B_1	Body height	0.55	0.65
B_2	Head height	0.56	0.31
B_3	Distance neck to hip	0.49	0.49
B_4	Neck diameter	0.39	0.33
B_5	Mid neck girth	0.29	0.37
B_6	Side upper torso length	0.36	0.43
B_7	Torso width	0.44	0.49
B_8	Total torso girth	0.39	0.56
B_9	Cross shoulder over neck	0.49	0.44
B_{10}	Cross shoulder	0.47	0.46
B_{11}	1/2 Shoulder width	0.63	0.60
B_{12}	Shoulder angle L (°)	0.33	0.33
B_{13}	Shoulder angle R (°)	0.58	0.39
B_{14}	Cross front width	0.52	0.51
B_{15}	Breast width	0.28	0.36
B_{16}	Neck R to waist over bust	0.25	0.35
B_{17}	Neck front to waist over bust	0.27	0.30
B_{18}	Bust points around neck	0.40	0.59
B_{19}	Bust point to neck	0.33	0.51
B_{20}	Chest band	0.19	0.39
B_{21}	Midriff girth	0.18	0.38
B_{22}	Cross back width	0.17	0.28
B_{23}	Back width	0.10	0.21
B_{24}	Neck to underarm back	0.31	0.31
B_{25}	Back length	0.37	0.41
B_{26}	Back length over shoulder blade	0.38	0.40
B_{27}	Distance armpit-waist	0.38	0.46
B_{28}	Waist to hip back	0.71	0.60
B_{29}	Waist girth	0.17	0.34
B_{30}	Waist to hip	0.79	0.59
B_{31}	Hip girth	0.30	0.45
B_{32}	Arm length to neck back	0.52	0.58
B_{33}	Arm length to neck	0.56	0.63
B_{34}	Arm length	0.57	0.65

9.4 Dress Shirt Pattern Design from 3D Body Measurements Using Artificial Neural Network

9.4.1 Application of Artificial Neural Network

The ANN pattern prediction model reported in Chapter 6 was used to generate the shirt patterns for subjects A and B according to their body measurements. The scaled data was written into a data file, named "input.dat" for program application. The output is the model is the scaled down pattern parameters, which is written into a file named "application.dat".

The scaled down pattern parameters in the file "application.dat" was then scaled up to derive shirt pattern measurements, using the following equation:

For converting back the results to original scale:

$$G = [\frac{(G'-0.1)}{0.8} \times (G_{max} - G_{min})] + G_{min} \qquad (9.2)$$

where,

G' = Predicted value of each pattern parameter

G = Pattern value in normal measurement

G_{min} = Minimum value of each pattern measurement

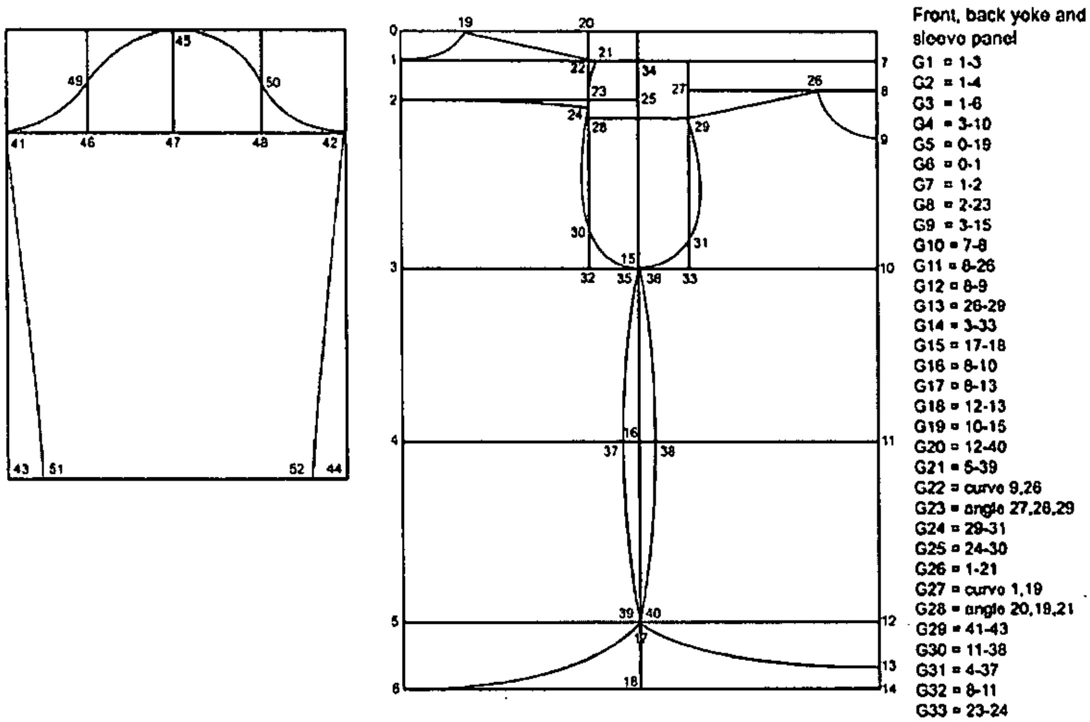
G_{max} = Maximum value of each pattern measurement

The pattern parameters calculated from the body measurements using the ANN model results are listed on Table 9.3. The definitions of the pattern parameters could be referred to Fig. 9.1.

Table 9.3 Pattern Measurements (in CM) Predicted from 3D Body Measurements Based on the ANN Model Reported in Chapter 6

Pattern Parameters	Subject A	Subject B
G_1	29.5	27.7
G_2	47.1	46.9
G_3	78.0	80.7
G_4	52.3	55.7
G_5	8.3	8.0
G_6	5.7	5.1
G_7	7.9	6.7
G_8	22.6	23.8.
G_9	26.2	27.7
G_{10}	7.5	3.6
G_{11}	5.9	6.5
G_{12}	4.9	6.3
G_{13}	16.1	16.3
G_{14}	31.8	33.9
G_{15}	6.6	8.7
G_{16}	22.1	24.4
G_{17}	69.7	77.1
G_{18}	5.7	8.1
G_{19}	26.1	27.9
G_{20}	26.0	27.8
G_{21}	26.0	27.5
G_{22}	8.1	9.7
G_{23}	20.1	19.0
G_{24}	14.7	12.7
G_{25}	16.5	15.0
G_{26}	24.2	24.3
G_{27}	11.5	10.4
G_{28}	13.3	11.2
G_{29}	42.7	44.4
G_{30}	23.5	26.0
G_{31}	23.2	25.8
G_{32}	40.8	42.4
G_{33}	2.8	1.4

Fig. 9.1 Shirt Pattern Parameters



9.4.2 Pattern Drafting and Shirt Making

The predicted 33 pattern parameters from 3D body measurements were used for drafting the paper patterns in accordance with the style illustrated in Fig. 9.1. The shirts were then made according to the derived paper patterns.

9.5 Evaluation of the Fitting of the Shirts Made According to the ANN Model Reported in Chapter 6

9.5.1 Wearer Trials

The finished dress shirts were tried on by subject A and B for subjective evaluation. They were required to rate the fitting in three different statuses, viz. standing still, uplifting both hands and bending forward of both hands at neckline, armhole, bodice and sleeve length. Figs 9.2 to 9.8 are the photos of shirt fitting for subject A. Figs 9.9 to 9.15 are the photos of shirt fitting for subject B.

Fig. 9.2 Shirt Fitting on Neckline and Shoulder

(Subject A)

Fig. 9.3 Front View of Shirt Fitting on Front Bodice, Armhole and Sleeve Length when Standing Still

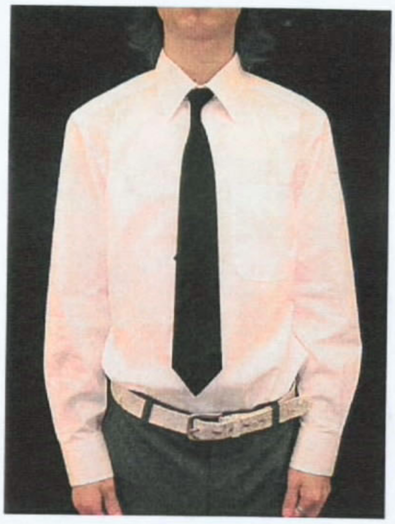


Fig. 9.4 Back View of Shirt Fitting on Back Bodice, Armhole and Sleeve Length when Standing Still

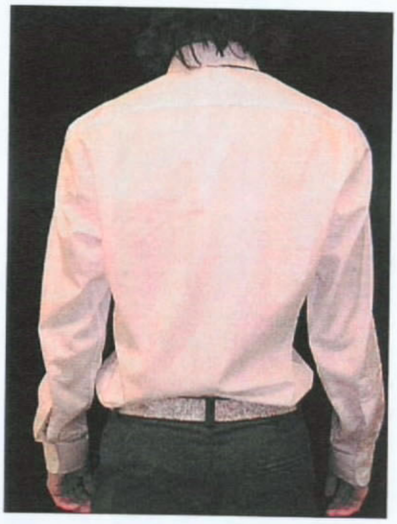


Fig. 9.5 Front View Shirt Fitting on Front Bodice and Armhole when Uplifting Both Hands

Fig. 9.6 Back View Shirt Fitting on Back Bodice and Armhole when Uplifting Both Hands

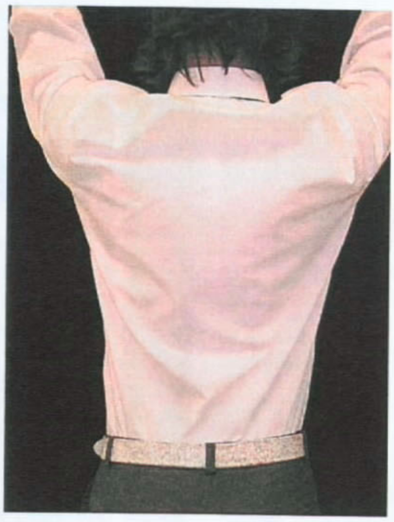


Fig. 9.7 Front View Shirt Fitting on Front Bodice and Armhole when Bending Both Hands Forward

Fig. 9.8 Back View Shirt Fitting on Back Bodice and Armhole when Bending Both Hands Forward

Fig. 9.9 Shirt Fitting on Neckline and Shoulder (Subject B)

Fig. 9.10 Front View of Shirt Fitting on Front Bodice, Armhole and Sleeve Length when Standing Still

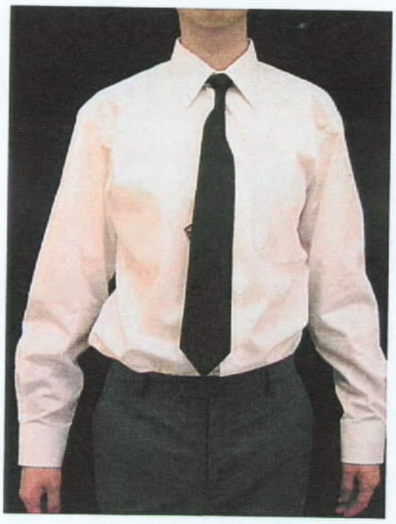


Fig. 9.11 Back View of Shirt Fitting on Back Bodice, Armhole and Sleeve Length when Standing Still

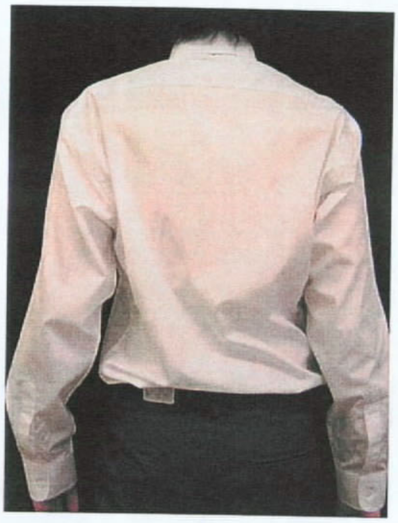


Fig. 9.12 Front View Shirt Fitting on Front Bodice and Armhole when Uplifting Both Hands

Fig. 9.13 Back View Shirt Fitting on Back Bodice and Armhole when Uplifting Both Hands

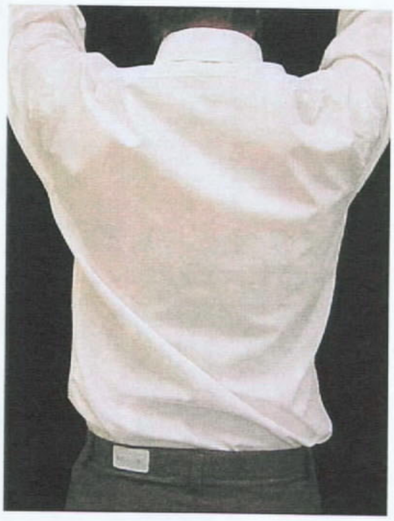


Fig. 9.14 Front View Shirt Fitting on Front Bodice and Armhole when Bending Both Hands Forward

Fig. 9.15 Back View Shirt Fitting on Back Bodice and Armhole when Bending Both Hands Forward

9.5.2 Subjective Assessment of Shirt Fitting for Shirts Made According to the ANN Model Reported in Chapter 6

The subjective ratings on the designed shirts are listed in Table 9.4. Fitting were assessed at the critical areas of shirts in a 1 to 5 scale, 1 being very tight and 5 being very loose when assessing the tightness or looseness, or 1 very short and 5 very long when assessing the length. The results show that all ratings for Subject B are 3, indicating that the dress shirt is very fit to him. As for Subject A, the ratings are mostly 3 with a few 4s, meaning that the shirt is fit to slightly loose. Note that Subject A is a very thin person, a slightly loose fitting may be appropriate for enhancing his body image (i.e. avoiding to be seen as too thin).

Subject A commented that the shirt is only slightly loose at the armhole. Generally, the shirt is nicely fit for him. He was satisfied with the looseness of the shirt for body movement. The rests of the shirt fitting area such as neckline, front and back of shirt and sleeve length provide adequate fit for wearing.

Subject B commented that the shirt is very fit for him especially at the armhole of the shirt. The amount of ease of shirt for body movement is adequate. It is not quite loose and tight on general appearance.

Table 9.4 Subjective Ratings of Subject A and B on Shirts Made According to the ANN Model Reported in Chapter 6

Subjective Parameters	Description	Subject A	Subject B
SR_1	Collar (with tie) When standing still	3	3
SR_2	Collar (with tie) When in movement	3	3
SR_3	Shoulder point location	4	3
SR_4	Armhole (When standing still)	4	3
SR_5	Armhole (When uplifting two hands)	4	3
SR_6	Armhole (When bending forward)	4	3
SR_7	Posture (When standing still)	3	3
SR_8	Posture (When uplifting two hands)	3	3
SR_9	Posture (When bending forward)	3	3
SR_{10}	Sleeve length	3	3
SR_{11}	Back (When uplifting two hands)	3	3
SR_{12}	Back (When bending forward)	3	3

9.6 Dress Shirt Pattern Design from 3D Body Measurements and Fitting Requirements Using ANN Model

9.6.1 Conversion of Input Data

In this section, two sets of data were used as inputs for the ANN model reported in Chapter 8 for deriving the pattern parameters. They were body parameters and fitting perceptions. Equation (9.1) was used for scaling the value of body parameters into the range between 0 to 1 and the converted values were the same as listed in Table 9.2. The requirements of fitting perception is 3 in all fitting areas, the corresponding scaled down value was 0.6.

9.6.2 Application of Artificial Neural Network Model

The Artificial Neural Network Model reported in Chapter 8 (i.e. Prediction of pattern parameters from body measurements and fitting requirements) was used to generate the shirt pattern for making shirts for subjects A and B. The scaled data was also written into a data file, named "input.dat" for program application. With the weights of the well-trained ANN model from Chapter 8, the model derived the scaled down pattern parameters in a result file named "application.dat".

The results from file "application.dat" were then scaled up to obtain actual pattern parameters using Equation (9.2). The predicted pattern measurements are listed in Table 9.5.

Table 9.5 Pattern Measurements (in CM) Predicted from the ANN Model Reported in Chapter 8

Pattern Parameters	Subject A	Subject B
G_1	31.7	31.3
G_2	49.8	49.3
G_3	83.6	82.1
G_4	55.7	55.6
G_5	8.9	9.0
G_6	5.7	5.6
G_7	8.5	8.4
G_8	24.6	24.2
G_9	27.9	27.9
G_{10}	7.7	7.7
G_{11}	6.0	6.1
G_{12}	4.6	4.9
G_{13}	17.7	17.2
G_{14}	34.1	34.4
G_{15}	6.7	6.7
G_{16}	24.1	23.6
G_{17}	75.0	73.3
G_{18}	5.9	5.9
G_{19}	27.8	27.8
G_{20}	28.6	28.6
G_{21}	28.6	28.6
G_{22}	8.0	8.2
G_{23}	21.4	21.7
G_{24}	15.1	14.6
G_{25}	17.6	17.0
G_{26}	26.1	25.8
G_{27}	12.1	12.0
G_{28}	12.5	12.5
G_{29}	48.6	46.3
G_{30}	25.1	25.2
G_{31}	25.1	25.2
G_{32}	45.0	44.3
G_{33}	3.3	3.4

9.6.3 Pattern Drafting and Shirt Making

The predicted 33 pattern parameters were then used for pattern drafting, and the shirts were made according to the finished paper pattern.

9.7 Evaluation of the Shirts Made According to the ANN Model Reported in Chapter 8

9.7.1 Wearer Trials

The finished dress shirts were tried on by Subject A and B for subjective evaluation. Three different exercises, viz. standing still, uplifting both hands and bending forward of both hands at neckline, armhole, bodice and sleeve length were performed before asked to rate the fitting. Figs 9.16 to 9.22 are the photos of shirt fitting for Subject A. Figs 9.23 to 9.29 are the photos of shirt fitting for Subject B.

Fig. 9.16 Shirt Fitting on Neckline and Shoulder

(Subject A on Second Prediction Model)

Fig. 9.17 Front View of Shirt Fitting on Front Bodice, Armhole and Sleeve Length when Standing Still

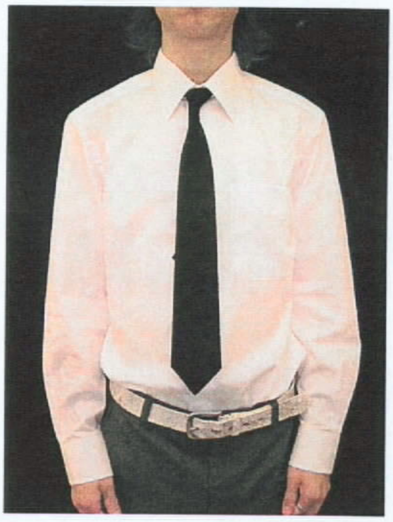


Fig. 9.18 Back View of Shirt Fitting on Back Bodice, Armhole and Sleeve Length when Standing Still

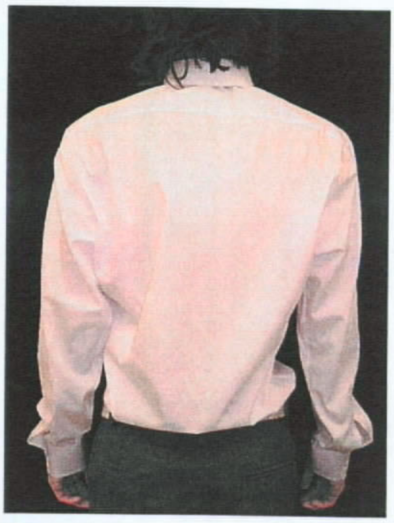


Fig. 9.19 Front View Shirt Fitting on Front Bodice and Armhole when Uplifting Both Hands

Fig. 9.20 Back View Shirt Fitting on Back Bodice and Armhole when Uplifting Both Hands

Fig. 9.21 Front View Shirt Fitting on Front Bodice and Armhole when Bending Both Hands Forward

Fig. 9.22 Back View Shirt Fitting on Back Bodice and Armhole when Bending Both Hands Forward

Fig. 9.23 Shirt Fitting on Neckline and Shoulder (Subject B on Second Prediction Model)

Fig. 9.24 Front View of Shirt Fitting on Front Bodice, Armhole and Sleeve Length when Standing Still

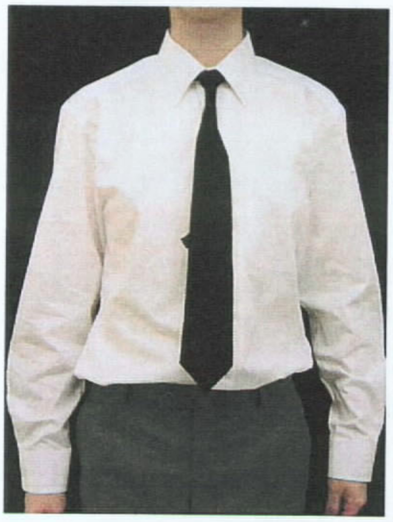


Fig. 9.25 Back View of Shirt Fitting on Back Bodice, Armhole and Sleeve Length when Standing Still

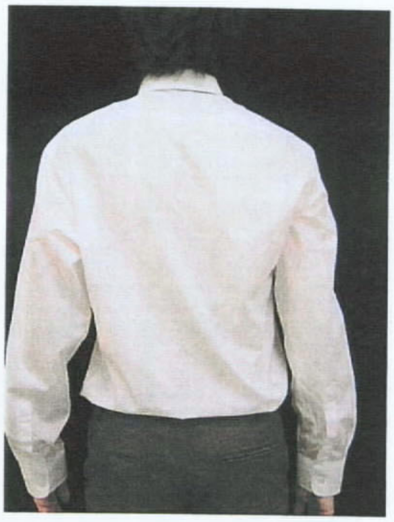


Fig. 9.26 Front View Shirt Fitting on Front Bodice and Armhole when Uplifting Both Hands

Fig. 9.27 Back View Shirt Fitting on Back Bodice and Armhole when Uplifting Both Hands

Fig. 9.28 Front View Shirt Fitting on Front Bodice and Armhole when Bending Both Hands Forward

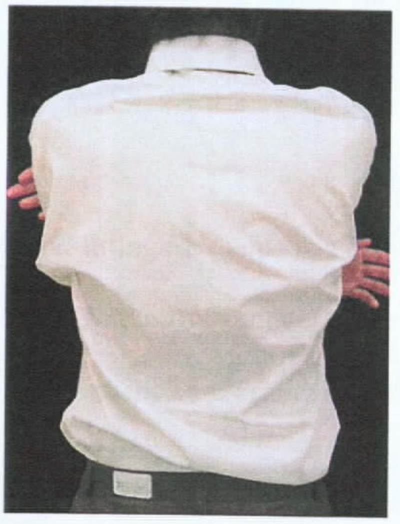


Fig. 9.29 Back View Shirt Fitting on Back Bodice and Armhole when Bending Both Hands Forward

9.7.2 Subjective Assessment of Shirts Made According to the ANN Model Reported in Chapter 8

The subject ratings of the designed shirts for Subject A and B using 3D body measurements and fitting requirements are listed on Table 9.6. All of the ratings are at the scale 3. This means the shirts provided very good fit to the two subjects.

Subject A and B agreed that these shirts provide very good fitting for them. The fitting of these two shirts are better than the shirts made according to the ANN model reported in Chapter 6. Although the shirts are tighter than previous one, the ease of movements is still adequate for them.

Table 9.6 Subjective Rating from Subject A and B from ANN Model Using 3D Body Measurements and Perception of Shit Fitting

Subjective Parameters	Description	Subject A	Subject B
SR_1	Collar (with tie) When standing still	3	3
SR_2	Collar (with tie) When in movement	3	3
SR_3	Shoulder point location	3	3
SR_4	Armhole (When standing still)	3	3
SR_5	Armhole (When uplifting two hands)	3	3
SR_6	Armhole (When bending forward)	3	3
SR_7	Posture (When standing still)	3	3
SR_8	Posture (When uplifting two hands)	3	3
SR_9	Posture (When bending forward)	3	3
SR_{10}	Sleeve length	3	3
SR_{11}	Back (When uplifting two hands)	3	3
SR_{12}	Back (When bending forward)	3	3

9.8 Conclusions

The shirt pattern prediction models developed and reported in Chapter 6 and 8 were applied to derive shirt patterns for two subjects, who were not included in the model building. Shirts were made according to the derived patterns and assessed for fitting. It has been shown that the shirts made according to both ANN models, in general, provide good fit to the wearers. It further confirmed that the two pattern prediction models are appropriate for pattern prediction.

Chapter 10

General Conclusions and Recommendations

Chapter 10

General Conclusions and Recommendations

10.1 General Conclusions

In order to implement mass customization in the apparel industry, it is essential to establish the quantitative relationship between the pattern parameters and 3D body measurements so that garment patterns fit to a specific individual could be drafted based on the wearer's 3D body measurements. In other words, garment patterns should be predicted from the fitting requirements and human body's anthropometrical measurements, so that patterns can be designed to meet the required appearance and fit for each individual.

The present study is focused on the pattern prediction of men's dress shirts. 59 male subjects, representing the Hong Kong Chinese population, were invited to participate in this study. The human subjects were scanned using a Tecmath Laser Scanner. Fitting shirts were made for each of the subjects and the pattern parameters of the fitting shirts for each subject were measured. In order to evaluate the effects of body and patterns on the fitting, the subjects were asked to put on not only their own fitting shirts, but also slightly unfit shirts. The fitting of subjects wearing different shirts were then assessed by the wearer himself and a panel of experts, during the course of which, the wearers were asked to perform different actions such as bending hands forward and uplifting hands.

From this experiment, a database containing body measurements, pattern measurements of men's dress shirts and fitting perceptions was established.

This database was used to evaluate traditional pattern drafting methods. The pattern measurements from 59 fitted shirts were compared with the calculated pattern parameters using four different tailoring experts' formulae. The results showed that the calculated pattern parameters using experts' formulae have very high deviations from the pattern measurements of the best-fit shirts. This is not caused by the possible differences between the manual ways of body measurements, traditional used by the tailoring experts for pattern drafting, and the body measurements using 3D body scanner, which were used in our calculation, since comparison between the manual body measurements and the body measurements from Tecmach body scanner showed no significant deference between two types of measurements, especially for those required by the traditional pattern formulae, such as neck girth, chest girth, waist girth, hip girth and sleeve length. This means that the patterns drafted using any of the four tailoring experts' methods cannot provide adequate fit to customers of diverse body shape. Improved pattern drafting formulae are required for individual fit, which is essential to the implementation of the much desired mass customization.

One possible reason for the inadequacy of these formulae is that human anthropometry changes with time. As a result, old formulae may not be appropriate for the present time. Another possible reason for the inadequacy of the traditional pattern drafting formulae is that each pattern parameter is only estimated from one or two body parameters, whereas in reality, one pattern parameter may be correlated with a multiple of body measurements. Multiple linear regression analysis was therefore conducted to investigate the relationships between the pattern parameters of fitting shirts and 3D body measurements. In this analysis, stepwise variable selection method was used to select important body measurements for predicting each pattern parameters. The results confirmed the initial hypothesis that each pattern parameter is in general related to a few body measurements. Pattern parameters predicted based on the Multiple Linear Regression Model (MRL) have significantly lower deviations from the pattern measurements of the best-fit shirts. The Multiple Linear Regression (MRL) Model is however still not sufficiently accurate for automatic pattern generation.

One possible reason for the insufficient effectiveness of the Multiple Linear Regression Model is that the model assumed that the relationship between each pattern parameter and the related body measurements are linear, whereas in reality, the relationship may be non-linear. In order to model the complex non-linear relationship, Artificial Neural Network (ANN) was applied. It was found that the ANN model for predicting the pattern parameters from 3D body measurements can have significant better prediction of the pattern parameters than the MLR model. It was found that the predictive errors of important pattern parameters (except for those affecting the style lines), based on 95% confidence interval, are less than 10%.

Artificial Neural Network has also been applied to model the interrelationship between 3D body measurements, pattern parameters of men's dress shirts and fitting perceptions.

An Artificial Neural Network model was established to predict the pattern parameters of men's dress shirts from both the 3D body measurements and fitting requirements. The results showed that the garment patterns predicted using the ANN is even more accurate. The predicted pattern parameters and actual fitting pattern parameters are very close with a squared correlation coefficient of 99%. Except for those pattern parameters affecting the shirt style, the prediction errors of critical pattern parameters are less than 8%.

Artificial Neural Network was also applied to establish a model for the prediction of the fitting perception of men's shirts from 3D body measurements and pattern parameters. The predicted fitting perception is generally accurate with the maximum deviations less than 0.9, which may be even smaller than the possible error a human observer can have in rating the fitting perception. The model can be used by the pattern designers to evaluate the pattern in terms of fitting to the target customer before an actual garment sample needs to be produced.

In order to further evaluate the validity and accuracy ANN models established in this study, dress shirts were made using the patterns predicted by the ANN models for two human subjects, who were not included in the model building. The shirts were assessed for fitting. It has been shown that the shirts made according to ANN models, in general, provide good fit to the wearers. It further confirmed that the ANN pattern prediction models are appropriate for pattern prediction.

The models developed in this study can be coded into a computer program for automatic pattern generation, which is much desired for the implementation of mass customization.

This study is significant as, for the first time, it provided a systematic experimental evaluation for the existing shirt pattern drafting formulae. It proves that each pattern parameter may be related to multiple body parameters in a complex no-linear relationship. The ANN models developed in the project are practical useful for automatic pattern generation of men's dress shirts. Although the present study is limited to men's dress shirts, the original methodology can be applied to the other types of garments in future studies.

10.2 Limitations

The first limitation in this study is that the time availability of the male subjects. These subjects were invited without any pay. Owing to the availability of the subjects and the time spent on body scanning, shirt making and wearer trials were huge, it is not possible to have too many human subjects in the study. The criterion of male subject selection is to cover a full range of sizes distribution of men dress shirt as specified in the industrial standards so as to represent the distribution of male Chinese population.

The time is also a major constraint in the fitting assessment. As it is meaningless to conduct fitting assessment for extremely unfit shirts for each wearer. Therefore, fitting assessments were only conducted for each wearer when wearing 10 different shirt samples including the one, which was tailor-made to best fit him. The principle is to ask the wearer to put on shirts with a neck size within 1 inch variation from his neck size.

Owing to the limited resources and time, this study is confined to men's dress shirt. And the fabric used in men's dress shirt is a typical cotton woven fabric in white colour. It would be ideal to have different types of fabrics in future studies.

10.3 Recommendations for Future Work

Owing to the limited resources and time, the study is confined to men's dress shirt. However, the methodology developed in this study can be applied for other types of garments.

Secondly, different fabrics can be included in the future study so as to establish pattern prediction models incorporating the effects of fabric properties in the pattern prediction.

Finally, automatic pattern drafting system can be programmed based on the models developed in this study for practical applications.

Appendices

Appendix I

Body Measurements (in CM)

	B1	B2	B3	B4	B5	B6	B7	B8	B9
Model 1	163.9	26.4	57.7	13.8	35.8	23.9	40.5	158.7	36.4
Model 2	176.9	27.8	64.1	13.7	36.6	28.7	40.0	172.4	37.4
Model 3	178.6	27.8	59.2	13.7	35.5	25.8	31.3	160.5	35.2
Model 4	173.3	26.0	58.7	14.5	37.9	22.5	39.6	167.4	36.4
Model 5	171.1	27.8	62.4	13.5	35.0	29.6	38.6	168.2	34.2
Model 6	179.8	27.8	61.0	14.0	36.1	22.8	35.8	163.4	35.9
Model 7	174.3	25.3	60.7	13.5	36.3	21.9	35.8	166.4	39.6
Model 8	175.1	28.2	59.6	14.7	42.5	21.4	34.2	180.7	43.0
Model 9	175.0	27.4	60.9	14.0	36.1	25.0	37.7	167.5	38.0
Model 10	168.2	27.4	60.2	14.4	37.9	23.9	30.8	166.4	34.6
Model 11	163.5	25.3	59.6	15.1	39.4	31.9	35.3	165.0	37.3
Model 12	172.9	27.8	63.2	14.0	35.4	34.8	37.3	171.6	33.8
Model 13	161.0	24.9	55.5	13.0	34.0	25.6	29.2	149.4	33.4
Model 14	170.4	27.1	60.2	14.8	38.5	30.8	32.2	163.0	35.5
Model 15	165.7	26.0	60.3	13.6	34.2	29.8	31.1	162.5	33.0
Model 16	174.3	28.9	60.1	13.8	36.4	25.9	30.6	160.7	32.1
Model 17	178.3	27.4	61.6	13.4	35.6	24.6	36.5	164.4	33.5
Model 18	185.9	27.4	63.6	13.9	37.9	33.1	37.2	173.4	38.3
Model 20	164.3	27.1	57.8	13.7	36.5	26.9	40.5	161.3	40.1
Model 21	171.4	27.8	57.2	12.7	34.6	18.0	32.3	158.2	41.1
Model 22	173.6	25.6	60.6	11.8	35.6	20.4	34.1	160.7	39.7
Model 23	169.7	24.5	58.4	12.1	35.0	22.0	32.6	157.6	40.3
Model 24	165.3	26.0	59.1	12.4	36.2	19.9	35.4	159.8	39.2
Model 25	169.9	25.3	60.3	11.3	33.4	20.4	29.2	158.4	38.1
Model 26	166.0	24.9	61.3	13.7	37.1	20.0	32.8	156.1	39.0
Model 27	171.4	23.8	60.4	11.6	35.2	22.1	32.6	155.8	39.4
Model 28	170.0	25.3	58.6	11.8	33.9	20.5	31.7	155.3	37.7
Model 29	163.2	25.6	56.2	11.9	33.9	18.7	28.5	152.1	39.7
Model 30	180.8	27.1	63.3	12.8	36.0	21.3	28.2	167.4	39.6
Model 31	163.5	24.6	56.0	13.1	36.5	17.9	33.1	150.6	39.5
Model 32	163.5	23.1	57.5	13.1	38.1	17.5	40.3	163.3	39.6
Model 33	164.2	25.3	55.3	11.2	32.2	18.2	31.6	151.2	37.8
Model 34	164.2	25.6	58.9	14.5	43.3	18.5	43.4	174.7	44.5
Model 35	167.7	26.0	59.2	12.0	32.7	22.4	32.6	153.6	36.8
Model 36	168.5	27.8	59.6	12.1	34.6	21.3	29.0	159.8	39.3
Model 37	169.7	26.0	60.8	12.7	35.7	19.9	31.2	157.9	41.5
Model 38	183.0	26.7	67.6	13.7	36.7	24.6	34.6	177.2	42.6
Model 39	173.3	27.4	60.9	12.8	35.1	21.9	31.6	161.9	41.7
Model 40	184.1	27.5	63.4	12.6	36.8	20.3	40.4	170.2	38.5
Model 41	170.7	25.3	64.7	13.6	39.1	21.5	37.9	173.0	41.0
Model 42	166.8	24.9	56.9	11.9	33.7	18.5	31.5	147.5	38.0
Model 43	175.1	26.0	59.6	14.6	36.8	21.1	37.7	159.4	40.4
Model 44	171.1	26.3	59.5	12.2	34.9	21.1	23.6	164.4	38.8
Model 45	174.0	26.4	63.1	12.7	35.6	22.1	28.4	161.7	40.1
Model 46	171.7	25.6	59.2	13.1	36.7	24.9	29.6	152.6	40.2
Model 47	166.0	24.9	59.0	12.1	33.5	22.8	30.0	155.4	35.8
Model 48	173.5	26.7	59.6	11.5	33.2	22.4	31.5	153.0	33.1
Model 49	171.4	27.5	60.0	12.6	34.4	23.5	34.8	162.3	35.8
Model 50	163.1	26.4	56.6	13.0	36.1	24.6	30.8	153.7	39.7
Model 51	177.2	27.4	63.9	13.3	36.1	24.7	27.2	166.2	40.2
Model 52	174.6	25.6	63.4	13.0	37.3	25.2	34.1	168.7	42.1
Model 53	170.3	24.9	60.1	13.3	38.7	26.0	32.8	164.9	38.6
Model 54	178.3	26.7	62.3	14.2	39.9	27.1	40.9	181.4	43.3
Model 55	182.4	27.6	64.2	12.8	36.1	24.5	35.0	165.3	38.8
Model 56	174.9	26.7	61.3	13.1	36.5	24.8	27.6	160.0	39.3
Model 57	181.5	27.1	63.3	12.0	33.0	22.5	31.6	164.8	39.3
Model 58	169.5	24.9	61.1	12.0	36.6	24.3	33.8	157.7	40.7
Model 59	183.9	26.0	67.4	13.2	38.4	25.8	34.7	177.0	40.1
Model 60	156.2	24.5	54.8	13.9	40.5	27.2	45.7	162.6	42.9
	B10	B11	B12	B13	B14	B15	B16	B17	B18

Model 1	40.4	10.7	22.1	25.7	33.8	38.6	45.9	39.6	68.8
Model 2	41.4	11.3	25.9	27.7	34.0	40.1	51.9	44.0	73.2
Model 3	38.8	10.3	19.6	26.2	33.1	36.4	45.7	36.7	74.3
Model 4	39.5	11.1	23.0	29.7	34.1	39.6	45.5	36.2	73.6
Model 5	37.7	9.8	23.2	33.5	31.4	36.4	54.4	44.5	78.4
Model 6	38.9	10.7	23.5	21.1	36.4	43.4	46.0	36.6	72.1
Model 7	44.4	12.6	27.7	27.7	36.0	42.4	45.2	36.6	78.2
Model 8	46.4	12.7	22.2	21.7	37.7	43.3	49.2	38.4	84.5
Model 9	40.6	11.4	20.0	17.1	38.5	43.4	48.7	38.6	75.6
Model 10	37.5	9.1	21.8	17.8	32.1	38.6	48.2	39.2	70.5
Model 11	40.0	10.9	25.7	24.7	36.9	41.6	53.7	43.8	73.4
Model 12	38.1	10.0	30.9	25.8	31.3	34.7	54.7	48.1	62.6
Model 13	35.7	9.9	28.6	24.8	31.4	35.8	47.9	40.7	66.1
Model 14	39.6	9.5	22.8	24.8	32.5	39.9	52.9	44.6	74.7
Model 15	35.4	9.2	23.0	19.6	30.2	37.8	51.5	44.2	64.3
Model 16	35.1	9.1	28.6	29.8	27.6	33.9	46.9	38.6	70.9
Model 17	36.9	9.7	31.6	31.4	32.0	40.6	50.3	43.7	86.6
Model 18	41.9	12.1	25.0	21.7	37.1	40.9	57.0	46.1	80.3
Model 20	43.0	12.0	23.8	22.6	37.8	44.0	52.4	47.2	73.0
Model 21	45.6	13.6	25.0	26.0	37.0	41.6	52.5	31.6	65.7
Model 22	42.7	14.0	25.0	25.0	36.1	39.8	41.9	30.8	70.3
Model 23	45.0	13.7	21.0	23.0	36.2	37.5	41.2	30.6	64.1
Model 24	42.2	13.1	24.0	24.0	37.5	42.6	42.1	30.7	68.1
Model 25	41.3	13.0	23.0	25.0	33.0	34.6	40.8	31.5	68.1
Model 26	42.7	12.9	29.0	32.0	33.9	36.0	40.8	30.3	69.6
Model 27	42.3	14.6	25.0	27.0	37.6	37.6	40.1	29.7	66.7
Model 28	40.3	13.5	21.0	20.0	35.9	38.1	39.8	29.6	65.8
Model 29	43.3	13.0	19.0	22.0	33.6	35.6	38.9	28.3	64.9
Model 30	45.1	12.9	27.0	31.0	32.3	35.4	41.6	32.8	67.0
Model 31	43.5	13.1	31.0	25.0	34.6	39.1	37.4	26.6	65.1
Model 32	42.8	13.3	24.0	23.0	37.7	42.6	39.6	29.9	67.5
Model 33	41.3	13.3	25.0	27.0	34.9	37.5	37.9	27.7	63.0
Model 34	48.6	14.2	25.0	24.0	41.5	44.9	43.1	33.3	77.0
Model 35	39.6	11.7	24.0	29.0	24.6	34.6	40.8	32.4	69.1
Model 36	42.1	14.0	20.0	22.0	37.2	38.6	39.3	29.0	63.7
Model 37	44.7	14.3	30.0	31.0	36.1	38.3	41.1	32.0	72.2
Model 38	46.1	14.5	29.0	27.0	38.3	40.2	47.1	34.9	76.2
Model 39	45.9	14.5	26.0	31.0	36.9	38.8	42.1	32.2	64.3
Model 40	41.1	12.9	29.0	28.0	35.7	42.2	44.6	34.1	76.5
Model 41	44.5	13.4	31.0	33.0	34.6	36.7	44.2	33.8	74.5
Model 42	40.7	12.6	28.0	23.0	33.7	35.9	38.2	28.8	63.4
Model 43	43.5	12.5	26.0	32.0	36.6	41.4	44.7	36.5	85.4
Model 44	43.2	12.7	18.0	18.0	34.7	35.9	41.0	30.1	64.0
Model 45	45.5	13.6	25.0	29.0	35.2	35.1	41.5	31.9	65.8
Model 46	43.3	13.3	28.0	32.0	35.4	37.0	39.8	30.9	66.6
Model 47	39.7	11.8	25.0	29.0	30.2	31.8	39.6	29.9	65.2
Model 48	35.7	10.9	19.0	27.0	29.7	33.2	39.4	30.8	64.2
Model 49	38.5	11.7	25.0	25.0	31.7	39.3	39.9	31.2	65.3
Model 50	44.1	12.9	26.0	31.0	35.9	40.7	40.8	30.8	65.4
Model 51	45.7	12.9	28.0	25.0	33.7	35.4	42.9	32.7	70.4
Model 52	47.0	14.2	32.0	31.0	35.7	39.9	42.7	31.4	65.7
Model 53	44.0	12.8	27.0	32.0	32.6	33.4	41.1	30.9	73.3
Model 54	48.2	14.3	26.0	23.0	40.6	44.9	44.9	33.8	75.9
Model 55	42.2	13.0	22.0	25.0	36.2	40.8	40.4	32.1	67.3
Model 56	42.4	13.2	31.0	32.0	33.0	33.8	41.7	30.3	70.2
Model 57	41.3	14.0	24.0	21.0	37.3	37.8	42.2	32.2	66.1
Model 58	44.1	14.6	26.0	32.0	37.0	37.0	37.8	27.8	56.3
Model 59	44.7	13.5	28.0	28.0	36.9	37.6	46.1	36.0	71.8
Model 60	47.1	14.6	23.0	23.0	44.5	46.1	40.9	30.9	73.9

	B19	B20	B21	B22	B23	B24	B25	B26	B27
Model 1	25.7	94.7	90.6	35.4	37.9	18.3	42.9	45.9	24.0
Model 2	28.3	87.3	83.8	36.0	37.5	17.8	48.9	51.8	29.6
Model 3	28.6	81.5	74.9	33.6	35.4	15.5	42.1	45.0	25.0
Model 4	26.7	89.6	85.6	36.3	38.6	18.6	42.4	46.6	23.5
Model 5	39.9	77.8	77.2	33.3	34.9	17.3	47.4	50.7	29.1
Model 6	27.1	87.4	83.3	33.2	35.5	17.8	42.7	45.2	23.8
Model 7	30.5	100.4	91.9	38.7	40.5	17.8	40.0	44.6	21.4
Model 8	32.1	118.9	113.1	41.9	44.9	19.9	41.0	44.5	20.4
Model 9	28.7	99.7	92.2	35.6	37.1	17.3	42.8	46.0	25.5
Model 10	26.5	90.9	85.3	32.4	34.2	17.5	41.9	44.6	23.5
Model 11	28.0	91.3	87.0	33.6	34.6	17.8	49.1	51.9	31.5
Model 12	22.6	89.1	80.1	34.6	36.9	19.2	53.2	56.7	34.9
Model 13	24.7	84.8	77.6	32.8	34.7	18.7	44.2	46.9	25.4
Model 14	28.3	93.9	90.2	36.1	38.9	16.7	47.0	50.9	29.4
Model 15	24.0	87.8	80.6	33.7	36.0	16.0	46.5	49.5	30.4
Model 16	26.5	84.7	81.2	35.7	39.7	17.2	43.6	48.4	26.3
Model 17	34.7	78.3	73.3	33.2	35.0	19.6	45.5	47.6	26.5
Model 18	31.4	102.0	92.0	37.7	39.7	18.1	52.0	55.3	33.0
Model 20	29.5	95.5	88.7	35.2	36.1	16.5	45.4	47.2	28.0
Model 21	24.7	95.7	88.3	37.0	36.7	16.0	34.7	38.5	17.9
Model 22	27.0	87.3	83.9	36.4	35.8	19.7	39.3	43.4	20.2
Model 23	24.2	90.3	81.4	38.4	38.3	16.6	39.5	44.5	21.9
Model 24	26.2	91.1	84.9	32.8	32.3	18.2	37.8	41.2	19.3
Model 25	25.4	85.2	79.3	35.7	36.3	17.5	38.7	42.5	20.1
Model 26	26.3	86.6	83.3	36.8	36.9	19.0	40.4	43.9	20.6
Model 27	25.2	79.5	77.5	33.3	32.0	18.2	41.6	46.3	22.3
Model 28	25.4	79.1	73.5	32.7	32.7	17.7	39.3	43.8	20.4
Model 29	24.6	85.4	79.2	37.6	37.3	16.1	35.9	39.6	19.9
Model 30	24.8	94.1	83.2	40.6	41.1	17.4	40.2	44.7	21.2
Model 31	24.1	83.7	78.2	36.7	35.7	18.6	36.7	40.8	17.8
Model 32	25.4	94.3	90.1	35.1	34.8	18.0	37.4	42.2	17.7
Model 33	24.1	80.2	76.8	33.4	32.8	17.2	35.7	40.8	17.7
Model 34	28.6	110.5	103.7	39.9	40.1	17.8	37.6	42.6	18.3
Model 35	26.6	72.7	72.0	39.8	39.7	19.4	39.3	42.1	19.1
Model 36	23.6	83.5	77.2	35.4	34.4	17.2	38.9	43.8	20.6
Model 37	27.8	86.3	81.1	37.1	36.8	18.2	39.0	43.1	19.2
Model 38	30.2	86.9	84.1	38.8	38.4	20.3	44.8	47.5	24.1
Model 39	23.9	93.5	84.9	39.1	39.3	18.0	41.0	45.5	21.6
Model 40	29.8	84.7	82.5	35.0	34.4	19.9	41.9	46.3	21.3
Model 41	27.8	89.2	85.2	36.3	36.3	18.8	41.4	46.2	21.7
Model 42	23.9	77.8	74.8	33.9	33.4	16.7	35.7	40.1	18.6
Model 43	34.2	79.6	76.5	35.2	34.6	17.4	42.4	44.4	22.6
Model 44	24.2	93.5	83.2	37.4	38.2	16.2	37.5	41.5	20.8
Model 45	24.6	82.5	77.0	36.9	36.5	17.1	39.8	44.6	22.0
Model 46	24.8	85.2	79.0	35.8	35.3	18.1	37.3	41.4	18.8
Model 47	24.8	80.1	74.6	34.6	34.8	17.2	37.8	41.8	20.7
Model 48	24.6	75.0	71.0	32.7	32.8	17.1	38.1	41.7	19.9
Model 49	24.8	83.2	77.6	33.5	33.1	16.2	37.6	41.6	21.8
Model 50	24.4	94.2	80.9	36.6	36.3	17.0	35.0	38.8	16.7
Model 51	26.6	89.5	83.2	39.7	39.4	17.8	39.8	43.9	21.7
Model 52	24.2	93.1	85.8	37.9	37.3	18.6	40.3	43.9	17.4
Model 53	27.7	93.6	89.7	39.0	38.7	18.9	40.9	46.2	20.7
Model 54	29.2	114.3	105.8	40.3	40.7	18.9	40.1	44.6	20.0
Model 55	25.1	86.7	84.0	34.2	33.4	15.9	38.4	43.0	20.7
Model 56	26.8	87.3	81.5	38.7	38.6	19.0	41.0	44.8	22.2
Model 57	25.8	86.3	79.3	36.1	36.0	17.0	41.0	44.8	23.0
Model 58	20.1	89.1	85.6	34.5	34.4	18.7	37.5	41.9	18.6
Model 59	26.9	92.9	85.1	36.6	36.2	17.3	43.1	47.9	24.8
Model 60	28.1	103.2	98.0	33.9	32.0	15.0	35.6	40.3	20.3

	B28	B29	B30	B31	B32	B33	B34
Model 1	17.2	88.1	52.7	95.3	76.3	68.7	58.0
Model 2	17.7	78.8	48.3	94.8	80.8	73.4	62.1
Model 3	20.3	68.2	44.3	89.2	80.9	73.5	63.3
Model 4	19.2	80.6	49.9	98.3	80.6	73.5	62.5
Model 5	17.3	83.9	50.6	94.5	79.5	72.1	62.4
Model 6	22.3	69.3	45.8	91.0	83.8	76.5	65.8
Model 7	21.2	82.8	52.0	97.3	84.0	76.3	64.0
Model 8	20.3	104.5	62.4	113.7	85.5	76.6	63.9
Model 9	19.8	83.1	51.5	96.2	79.4	71.5	60.2
Model 10	20.8	76.0	48.4	92.9	78.1	69.5	60.7
Model 11	13.9	82.8	48.4	93.9	76.0	68.1	57.3
Model 12	12.4	80.3	46.4	93.2	75.9	68.8	58.9
Model 13	12.7	71.2	42.0	85.6	76.1	69.4	59.5
Model 14	14.7	77.5	46.1	89.8	78.8	70.5	60.9
Model 15	14.9	68.4	41.7	85.9	74.9	67.5	58.4
Model 16	18.0	69.9	44.0	89.3	79.8	72.8	63.8
Model 17	19.6	72.7	46.2	91.4	80.0	72.9	63.2
Model 18	14.4	87.9	51.2	99.4	87.8	80.6	68.6
Model 20	15.3	83.6	49.5	96.6	78.3	70.3	58.3
Model 21	23.4	72.7	48.1	91.7	82.3	75.2	61.7
Model 22	22.5	72.6	47.6	88.5	83.1	77.2	63.2
Model 23	21.1	73.7	47.4	88.8	83.8	77.4	63.6
Model 24	24.0	75.5	49.8	88.8	74.9	68.4	55.3
Model 25	23.3	72.0	47.7	91.1	82.2	76.0	63.0
Model 26	23.4	74.3	48.9	91.3	79.1	72.4	59.6
Model 27	23.0	68.0	45.5	88.6	78.5	73.3	58.8
Model 28	22.2	64.8	43.5	87.9	80.8	75.5	62.0
Model 29	22.3	70.8	46.6	90.4	81.0	74.0	61.1
Model 30	24.8	73.9	49.4	93.1	84.7	77.7	64.9
Model 31	22.2	69.2	45.7	87.4	75.1	68.5	55.4
Model 32	21.8	82.8	52.3	94.8	78.6	72.1	58.8
Model 33	21.6	66.3	44.0	84.2	80.2	74.6	61.3
Model 34	23.0	99.3	61.2	106.1	78.9	70.6	56.4
Model 35	22.4	63.9	22.6	84.1	80.3	73.8	62.0
Model 36	22.4	69.6	46.0	86.8	78.0	72.1	58.2
Model 37	22.8	72.0	47.4	91.2	82.7	76.2	61.9
Model 38	25.1	75.5	50.3	93.6	86.3	79.4	65.0
Model 39	22.0	76.5	49.3	96.6	83.5	77.1	62.6
Model 40	23.1	76.9	50.0	90.7	86.0	79.6	66.7
Model 41	24.8	82.0	53.4	100.9	79.3	72.1	58.7
Model 42	21.7	65.7	43.7	81.0	79.8	73.4	60.8
Model 43	21.5	74.4	48.0	91.6	85.6	77.9	65.4
Model 44	23.2	74.4	48.8	94.2	81.4	74.6	61.8
Model 45	24.2	70.3	47.3	90.4	81.0	74.5	61.0
Model 46	22.5	68.9	23.0	84.8	81.7	74.8	61.6
Model 47	22.4	68.2	23.0	86.2	76.3	70.1	58.3
Model 48	22.8	65.6	23.3	82.4	77.3	71.6	60.8
Model 49	23.4	71.7	23.6	85.1	76.4	70.3	58.6
Model 50	22.3	73.5	22.9	88.7	77.9	70.9	57.9
Model 51	24.7	75.7	27.3	97.3	84.5	77.2	64.4
Model 52	24.8	77.8	25.1	96.6	83.1	76.2	62.0
Model 53	21.8	85.7	21.9	101.5	81.4	74.9	62.1
Model 54	23.7	98.4	23.8	109.7	83.9	76.5	62.2
Model 55	27.4	73.4	27.1	91.6	82.8	76.4	63.4
Model 56	22.8	74.1	23.2	92.7	80.1	73.7	60.5
Model 57	24.1	71.9	24.5	89.4	85.1	79.4	65.5
Model 58	25.4	77.6	25.2	90.4	80.0	74.2	59.7
Model 59	26.5	79.7	26.1	100.9	84.7	78.1	64.7
Model 60	21.1	94.1	20.8	98.6	72.3	65.4	50.8

Appendix II

Pattern Measurements (in CM)

	G1	G2	G3	G4	G5	G6	G7	G8	G9
Model 1	28.0	43.8	76.7	53.6	8.3	4.7	7.0	23.0	26.7
Model 2	27.6	50.0	79.5	55.8	8.3	5.0	6.9	24.5	27.9
Model 3	28.2	43.3	78.4	51.0	8.4	4.8	7.0	24.3	25.4
Model 4	28.3	47.6	80.6	55.9	8.3	4.8	7.7	23.5	27.8
Model 5	27.7	44.1	79.9	53.4	7.9	4.7	7.4	23.5	26.6
Model 6	27.1	47.7	80.5	55.1	8.3	5.2	6.8	22.7	27.4
Model 7	29.6	50.2	82.9	59.4	8.6	5.4	6.9	24.7	29.6
Model 8	29.9	57.9	86.9	69.5	9.1	5.0	7.2	25.2	34.6
Model 9	29.0	47.3	82.8	57.6	8.1	4.7	7.6	23.5	28.7
Model 10	27.8	47.8	81.1	53.2	8.3	5.1	7.2	22.6	26.5
Model 11	27.6	47.9	76.8	55.1	8.3	5.0	6.9	22.7	27.5
Model 12	28.2	45.9	80.0	53.1	8.0	5.1	6.9	23.3	26.5
Model 13	27.5	45.0	75.7	52.3	7.8	5.2	7.1	22.1	26.1
Model 14	27.9	49.7	79.3	57.1	8.3	4.9	7.2	22.6	28.4
Model 15	27.7	46.8	80.1	51.2	7.8	4.8	7.2	22.7	25.4
Model 16	28.8	47.7	82.6	52.8	8.3	5.0	7.3	24.1	26.3
Model 17	28.8	49.7	83.2	53.4	8.1	5.0	7.4	23.4	26.6
Model 18	30.2	52.2	84.6	58.4	8.2	4.9	7.1	24.5	29.2
Model 20	27.7	47.0	78.4	55.8	8.2	5.1	7.0	24.5	27.8
Model 21	30.7	48.9	79.4	55.8	8.8	5.5	8.3	22.9	27.9
Model 22	29.5	49.0	81.1	53.1	8.3	5.5	8.3	22.1	26.6
Model 23	30.3	49.5	81.8	55.5	8.8	5.7	8.5	23.7	27.7
Model 24	29.1	46.3	76.8	54.3	8.4	5.6	8.3	22.4	27.2
Model 25	29.1	46.6	79.4	51.9	8.3	5.7	8.2	23.2	26.0
Model 26	30.3	47.0	78.5	54.1	8.7	5.5	8.4	23.7	27.1
Model 27	29.4	46.8	79.1	51.8	8.6	5.7	8.1	22.4	25.9
Model 28	28.3	47.0	77.0	53.5	8.4	5.5	8.3	21.3	26.7
Model 29	30.0	47.9	79.5	53.4	8.5	5.6	8.2	23.2	26.7
Model 30	30.2	51.2	84.2	54.3	8.5	5.7	8.1	23.7	27.2
Model 31	29.7	46.3	76.7	51.8	9.0	5.5	8.3	22.5	25.9
Model 32	29.9	49.7	79.2	56.9	9.1	5.4	8.4	23.2	28.5
Model 33	29.9	48.3	78.8	52.6	8.4	5.6	8.3	22.4	26.3
Model 34	32.0	53.5	82.1	63.9	9.8	5.6	8.2	24.7	32.1
Model 35	29.0	48.3	77.3	52.4	8.2	5.4	8.4	22.7	25.3
Model 36	28.7	48.8	78.8	52.9	8.3	5.7	8.1	22.4	26.4
Model 37	30.5	47.8	79.8	52.9	8.4	5.5	8.4	23.6	26.5
Model 38	31.8	48.9	83.3	55.3	8.7	5.6	8.5	25.0	27.6
Model 39	31.6	47.6	79.4	56.8	8.7	5.5	8.4	25.1	28.5
Model 40	31.1	48.6	82.0	55.1	8.8	5.7	8.2	23.7	27.6
Model 41	32.0	50.5	83.2	54.4	9.2	5.5	8.4	24.3	27.2
Model 42	28.7	45.8	77.0	49.7	8.4	5.5	8.3	21.9	24.9
Model 43	31.2	47.1	82.2	55.5	9.0	5.7	8.2	23.7	27.8
Model 44	29.8	48.5	79.5	55.7	8.7	5.6	8.2	23.6	28.0
Model 45	29.9	47.4	82.0	51.5	8.4	5.6	8.2	23.6	25.8
Model 46	29.7	45.7	75.4	52.9	8.0	5.7	6.8	23.5	26.3
Model 47	27.5	44.0	72.4	51.1	7.5	5.5	7.0	21.2	25.5
Model 48	27.5	45.0	75.6	48.3	7.7	5.4	7.0	21.1	24.1
Model 49	28.9	44.9	73.1	51.6	8.0	5.3	7.0	22.0	25.8
Model 50	30.3	44.8	74.9	54.9	8.0	5.7	7.0	22.7	27.2
Model 51	28.9	44.9	75.7	54.1	8.4	5.6	7.0	23.4	27.2
Model 52	29.8	46.1	75.5	55.0	8.0	5.7	7.1	24.1	27.6
Model 53	30.2	48.2	78.3	59.5	8.0	5.7	6.8	25.3	29.8
Model 54	29.2	48.2	81.3	65.0	8.4	5.5	6.8	24.7	32.4
Model 55	27.8	45.8	78.2	52.9	7.7	5.5	7.0	22.6	26.5
Model 56	28.5	45.5	78.8	53.7	8.5	5.2	7.1	22.5	26.7
Model 57	27.9	44.9	77.2	53.7	7.6	5.5	6.8	23.6	26.9
Model 58	28.9	45.4	77.8	52.8	8.0	5.7	6.9	23.3	26.3
Model 59	29.2	49.2	81.7	56.1	8.1	5.5	7.0	23.6	28.0
Model 60	28.8	48.6	75.5	61.8	8.6	5.6	6.9	23.4	30.9
	G10	G11	G12	G13	G14	G15	G16	G17	G18

Model 1	3.8	6.4	5.3	15.5	33.0	7.1	24.2	72.1	6.4
Model 2	4.0	6.6	5.7	17.0	33.3	7.9	23.6	75.1	7.5
Model 3	4.2	6.6	5.5	17.0	28.7	7.0	24.0	73.9	6.9
Model 4	4.6	6.2	5.9	16.6	34.2	8.2	23.7	75.3	7.7
Model 5	4.7	5.6	5.3	16.8	31.9	7.4	23.0	74.8	7.2
Model 6	3.5	6.3	5.7	15.5	34.6	9.4	23.6	76.3	8.7
Model 7	3.4	6.5	6.1	17.2	37.1	8.7	26.2	78.9	8.2
Model 8	4.0	7.5	6.2	16.9	46.1	8.7	25.9	82.4	8.3
Model 9	4.7	5.8	5.8	16.4	36.5	7.0	24.3	77.8	6.6
Model 10	4.4	6.3	6.1	15.7	32.6	7.9	23.4	76.1	7.5
Model 11	3.9	6.4	6.1	15.6	34.4	8.3	23.7	72.2	7.7
Model 12	3.9	6.1	5.3	16.7	32.1	8.3	24.3	75.3	7.8
Model 13	3.6	5.6	5.4	15.5	32.3	8.4	23.9	71.7	8.3
Model 14	4.2	6.5	6.0	15.1	36.5	7.4	23.7	74.4	7.0
Model 15	4.1	6.1	5.4	15.7	30.5	7.5	23.6	75.1	7.0
Model 16	4.4	6.3	5.3	16.8	30.8	8.0	24.4	77.2	7.1
Model 17	3.6	6.3	5.4	16.6	32.0	8.6	25.3	79.0	8.2
Model 18	4.2	6.3	5.5	17.3	35.8	8.5	26.0	79.8	7.7
Model 20	3.9	6.5	6.0	17.1	32.8	8.8	23.8	73.8	8.3
Model 21	7.1	5.6	3.9	16.5	34.8	6.7	23.6	71.1	5.7
Model 22	7.7	5.7	4.1	15.8	33.6	6.7	21.8	72.4	5.8
Model 23	6.7	6.3	4.3	16.7	33.4	6.6	23.6	74.0	5.6
Model 24	6.9	5.7	4.5	16.0	34.0	6.7	22.2	68.6	5.6
Model 25	6.9	5.6	4.3	16.6	31.0	6.2	22.2	71.0	4.9
Model 26	7.5	5.8	4.3	16.7	32.6	6.7	22.8	69.9	5.6
Model 27	7.4	5.8	4.8	16.0	32.1	6.4	22.0	70.9	5.8
Model 28	7.5	5.7	4.2	14.8	34.2	6.5	20.8	68.4	5.7
Model 29	7.1	5.6	3.6	16.7	32.2	7.2	22.9	71.3	5.8
Model 30	7.2	5.9	4.0	17.1	32.7	6.5	23.0	76.3	6.0
Model 31	7.5	6.2	4.9	15.5	31.7	6.5	22.2	68.2	5.8
Model 32	7.2	6.4	4.1	16.1	35.5	6.5	22.7	71.2	6.0
Model 33	7.7	5.5	4.3	16.2	32.9	6.7	22.2	69.9	5.8
Model 34	7.2	7.4	6.1	16.8	40.9	6.9	24.8	73.7	6.0
Model 35	7.5	5.6	4.3	16.2	31.9	6.5	21.5	68.9	5.7
Model 36	6.9	5.5	4.2	16.5	32.3	6.6	21.8	71.2	5.9
Model 37	7.5	5.6	4.6	17.3	32.4	6.7	18.4	71.5	5.9
Model 38	7.4	5.9	4.8	18.3	32.8	6.8	24.4	74.9	5.8
Model 39	7.5	5.9	4.4	18.1	34.8	6.6	24.1	71.1	6.0
Model 40	7.5	5.9	4.8	16.9	34.4	6.8	23.6	73.7	6.3
Model 41	8.6	6.3	5.8	17.0	34.7	6.9	23.4	73.7	6.2
Model 42	7.5	5.7	3.8	15.8	29.4	6.4	21.2	68.6	5.6
Model 43	7.4	6.1	4.5	17.1	33.3	7.3	23.8	73.6	6.1
Model 44	7.3	5.7	4.8	17.2	34.5	6.6	22.5	71.2	5.7
Model 45	7.3	5.6	4.8	17.0	30.6	6.6	22.6	73.8	5.7
Model 46	5.3	5.9	5.5	16.8	31.3	7.0	24.4	69.4	6.0
Model 47	5.5	6.1	5.4	14.3	31.5	7.5	22.0	66.7	7.1
Model 48	5.3	5.8	5.1	14.7	28.7	7.2	22.2	69.2	6.5
Model 49	5.2	6.0	5.7	15.5	31.2	8.3	23.7	66.8	7.2
Model 50	5.7	6.5	5.8	15.5	33.8	8.0	24.6	69.1	6.7
Model 51	5.4	5.9	5.7	16.3	32.8	8.0	23.5	69.6	7.4
Model 52	4.6	6.1	5.6	17.0	32.8	8.7	25.2	69.4	7.3
Model 53	4.1	6.3	5.8	18.3	36.2	7.1	26.1	72.9	6.9
Model 54	5.3	7.2	6.2	16.3	42.0	8.0	23.9	75.1	7.2
Model 55	5.1	6.3	5.5	15.2	31.9	8.2	22.7	71.5	6.6
Model 56	4.8	6.3	5.9	15.4	32.7	8.2	23.7	72.4	6.8
Model 57	5.4	5.8	5.0	16.7	32.0	6.7	22.5	71.2	6.0
Model 58	4.9	6.5	5.8	16.2	31.0	6.6	24.0	72.0	5.6
Model 59	5.1	6.5	5.9	16.2	34.3	8.0	24.1	76.2	7.5
Model 60	5.3	7.0	6.7	15.4	40.2	7.2	23.5	69.6	6.6

	G19	G20	G21	G22	G23	G24	G25	G26	G27
Model 1	26.9	26.7	26.6	8.6	23.0	11.6	13.0	23.6	10.4
Model 2	27.9	27.9	27.5	9.3	21.0	12.8	15.0	25.2	10.7
Model 3	25.6	26.0	25.8	9.1	20.0	15.0	17.6	25.1	10.7
Model 4	28.1	27.9	27.7	9.2	20.0	11.6	13.5	24.7	10.5
Model 5	26.8	26.5	26.3	8.2	19.0	12.5	14.6	24.4	10.1
Model 6	27.7	27.9	27.8	9.0	21.0	8.5	11.9	23.4	10.8
Model 7	29.8	30.2	29.9	9.5	21.0	12.9	15.3	25.6	11.2
Model 8	34.9	34.9	34.8	10.4	19.5	8.6	10.8	25.8	11.5
Model 9	28.9	29.1	28.9	8.7	21.0	9.8	13.5	24.3	10.1
Model 10	26.7	26.9	26.7	9.2	20.0	12.0	13.9	23.5	10.8
Model 11	27.6	27.9	27.7	9.2	20.0	11.0	10.1	23.6	10.6
Model 12	26.6	27.3	27.2	8.4	21.0	13.5	14.5	24.4	10.5
Model 13	26.2	25.8	25.6	8.1	22.0	11.7	13.5	22.8	10.5
Model 14	28.7	28.6	28.5	9.4	22.0	9.8	12.2	23.4	10.6
Model 15	25.8	25.7	25.5	8.6	22.0	13.3	15.5	23.3	10.0
Model 16	26.5	26.4	26.3	8.7	22.0	13.0	.16.0	24.9	10.8
Model 17	26.8	26.4	26.2	8.8	24.5	12.8	14.4	24.5	10.5
Model 18	29.2	28.7	28.7	8.8	20.0	13.6	16.6	25.4	10.8
Model 20	28.0	27.9	27.7	9.5	19.0	12.7	14.8	25.4	10.6
Model 21	27.9	27.4	27.5	7.3	21.0	13.6	15.6	24.7	11.7
Model 22	26.5	27.4	27.5	7.4	22.0	12.4	15.0	23.5	11.4
Model 23	27.8	27.4	27.3	8.1	20.0	14.4	15.5	25.3	11.8
Model 24	27.1	27.4	27.5	7.7	22.0	13.1	14.4	23.8	11.6
Model 25	25.9	26.2	26.3	7.6	22.0	13.5	15.8	24.4	11.6
Model 26	27.0	26.9	26.9	7.7	21.0	14.2	15.9	25.0	11.6
Model 27	25.9	26.8	26.6	7.9	21.5	13.2	15.6	24.2	11.7
Model 28	26.8	27.0	26.9	7.5	21.0	10.8	13.8	22.8	11.4
Model 29	26.7	26.1	26.0	7.0	21.5	13.6	15.5	24.7	11.7
Model 30	27.1	27.5	27.6	7.5	21.0	14.5	16.1	25.2	11.7
Model 31	25.9	26.0	26.1	8.3	24.5	13.0	15.5	24.1	11.8
Model 32	28.4	28.0	28.1	8.2	21.0	12.6	14.8	24.8	12.1
Model 33	26.3	26.7	26.6	7.4	21.0	13.3	15.5	24.0	11.7
Model 34	31.8	31.9	32.1	10.4	21.0	13.5	13.9	26.3	12.8
Model 35	25.2	26.1	26.3	7.4	23.0	13.2	15.5	23.9	11.4
Model 36	26.5	27.0	27.0	7.4	19.0	13.8	15.2	24.2	11.4
Model 37	26.4	27.6	27.4	7.6	22.0	14.8	16.7	25.1	11.2
Model 38	27.7	28.2	28.0	8.2	20.0	15.7	17.9	26.6	11.9
Model 39	28.3	29.2	29.3	7.8	21.0	14.8	17.4	26.5	11.5
Model 40	27.5	28.5	28.7	8.1	21.0	15.0	17.2	25.2	12.0
Model 41	27.2	29.4	29.4	8.7	24.0	14.2	17.7	25.8	12.1
Model 42	24.8	24.5	24.3	7.2	22.0	13.4	15.0	23.7	11.3
Model 43	27.7	27.4	27.4	8.0	21.0	14.5	16.9	25.5	12.0
Model 44	27.7	28.5	28.7	8.0	17.0	14.4	16.3	25.3	11.6
Model 45	25.7	26.3	26.3	7.7	22.0	14.6	17.1	25.1	11.6
Model 46	26.6	24.7	24.8	8.5	22.0	15.7	17.4	24.4	10.9
Model 47	25.6	25.1	25.0	8.7	21.0	13.6	15.7	22.1	10.3
Model 48	24.2	23.8	23.5	8.2	20.0	13.7	15.3	22.1	10.5
Model 49	25.8	25.0	25.0	8.8	22.0	14.4	16.3	23.3	10.8
Model 50	27.7	26.2	26.5	9.4	21.0	14.7	16.4	23.5	11.0
Model 51	26.9	26.8	26.4	8.7	19.0	14.9	16.5	24.3	11.3
Model 52	27.4	27.0	26.7	8.8	20.0	15.8	17.4	25.0	11.0
Model 53	29.7	29.0	28.5	9.1	23.0	14.9	17.4	26.0	11.0
Model 54	32.6	32.2	31.9	10.1	17.0	13.7	12.9	25.4	11.2
Model 55	26.4	24.3	24.4	9.0	17.0	15.2	15.8	23.2	10.8
Model 56	27.0	26.4	26.4	9.1	19.0	14.3	16.5	23.6	11.0
Model 57	26.8	25.7	25.7	8.0	21.0	14.4	16.8	24.3	10.4
Model 58	26.5	26.1	26.0	9.3	20.0	15.9	17.2	24.2	11.1
Model 59	28.1	27.7	27.2	9.3	21.0	14.0	16.0	24.4	10.9
Model 60	30.9	29.4	29.1	10.3	20.0	12.3	13.3	24.1	11.4

	G28	G29	G30	G31	G32	G33
Model 1	13.0	40.9	24.5	24.3	42.2	1.6
Model 2	11.0	43.7	25.0	24.9	45.6	1.8
Model 3	12.0	45.6	23.4	23.3	41.6	2.1
Model 4	12.0	43.7	25.7	25.4	43.3	2.0
Model 5	11.0	41.8	25.3	25.2	39.9	1.8
Model 6	12.0	46.6	25.2	25.0	44.1	1.6
Model 7	13.0	45.0	27.0	26.8	46.2	1.7
Model 8	10.0	46.2	32.1	31.8	47.3	1.7
Model 9	13.0	44.3	26.9	26.7	42.1	1.8
Model 10	11.5	39.9	24.8	24.6	42.9	1.8
Model 11	11.0	38.1	25.4	25.2	44.1	1.5
Model 12	12.0	38.8	23.9	23.9	44.2	2.0
Model 13	14.0	40.1	23.6	23.5	41.9	1.8
Model 14	11.5	42.5	25.5	25.1	44.5	2.1
Model 15	12.0	37.2	22.4	22.2	44.0	1.8
Model 16	11.0	44.0	23.9	23.7	47.2	2.0
Model 17	13.0	43.5	24.6	24.4	48.0	2.3
Model 18	9.0	49.5	28.1	27.9	49.1	2.0
Model 20	10.0	40.2	26.9	26.6	41.8	1.5
Model 21	13.5	46.8	22.3	22.3	44.9	3.1
Model 22	13.0	49.6	23.5	23.6	44.2	3.1
Model 23	13.5	46.6	23.4	23.4	45.3	1.9
Model 24	14.0	42.3	23.4	23.6	41.7	3.0
Model 25	12.0	46.3	23.4	23.4	41.6	3.1
Model 26	13.0	42.8	22.8	23.0	43.5	3.1
Model 27	14.0	44.9	22.2	22.1	41.6	3.1
Model 28	14.0	45.2	22.3	22.4	40.4	2.6
Model 29	14.0	43.1	22.6	22.6	44.2	3.4
Model 30	12.0	47.5	22.9	23.0	46.0	3.1
Model 31	13.0	41.7	22.0	22.0	42.9	3.6
Model 32	13.0	43.8	25.9	25.8	43.9	2.5
Model 33	13.0	45.2	27.2	27.1	43.1	3.0
Model 34	13.0	41.2	30.3	30.5	46.3	2.5
Model 35	13.0	44.1	20.7	20.9	41.3	3.2
Model 36	14.0	42.9	23.5	23.4	42.6	2.8
Model 37	13.0	45.4	23.5	23.4	38.9	3.5
Model 38	13.0	49.9	24.1	24.1	45.0	3.2
Model 39	12.0	44.5	24.6	24.9	42.6	3.4
Model 40	13.0	49.5	25.9	26.0	43.8	3.2
Model 41	12.0	43.6	26.0	25.8	43.9	4.2
Model 42	14.0	44.6	22.3	22.1	42.0	3.3
Model 43	12.0	47.4	24.0	24.0	42.9	3.3
Model 44	13.0	44.9	23.5	23.7	42.6	2.5
Model 45	13.0	44.8	22.1	22.3	43.3	3.3
Model 46	13.0	41.5	22.6	22.5	41.9	3.3
Model 47	13.0	37.5	21.2	21.1	38.0	1.7
Model 48	15.0	41.6	21.4	21.1	38.4	2.1
Model 49	13.0	40.8	22.8	22.5	40.2	2.1
Model 50	13.0	38.3	24.1	24.0	40.6	2.7
Model 51	12.0	45.7	23.7	23.6	39.5	2.1
Model 52	13.0	45.5	23.4	23.5	40.1	1.8
Model 53	10.0	42.6	29.7	29.8	43.7	2.0
Model 54	11.0	44.8	30.7	32.4	41.4	1.5
Model 55	13.0	43.8	23.5	23.4	41.2	1.5
Model 56	12.0	44.0	23.5	23.3	41.7	1.8
Model 57	13.0	46.9	23.4	23.3	39.5	1.6
Model 58	14.0	41.6	23.4	23.2	42.0	1.8
Model 59	11.0	45.0	25.3	24.9	43.1	1.6
Model 60	12.0	38.7	28.4	28.3	43.3	2.5

Appendix III

Subjective Rating (Average)

	1.1	1.2	2.1	3.1	3.2	3.3	4.1	4.2	4.3	5.1	6.1	6.2
01#01	3.0	3.0	3.2	3.2	3.0	3.0	3.0	3.0	3.2	3.2	3.0	2.8
01#02	3.4	3.6	3.8	3.5	3.0	3.0	3.8	3.6	3.3	3.2	3.3	3.3
01#03	3.0	3.0	3.8	3.3	3.0	3.0	3.5	3.0	3.0	3.5	3.0	3.0
01#05	2.4	2.4	3.6	3.3	2.8	3.0	4.0	3.3	3.3	3.0	2.8	3.2
01#06	3.2	3.4	3.2	3.5	2.8	3.3	3.7	3.3	3.3	3.5	3.3	3.3
01#10	3.4	3.4	3.5	3.5	3.3	3.3	3.2	3.0	3.0	2.8	3.5	3.3
01#13	2.4	2.4	2.7	3.0	2.6	2.8	3.2	3.0	3.0	2.8	3.2	2.8
01#15	2.2	2.2	3.2	3.0	2.6	2.8	2.5	2.5	2.5	3.2	2.8	2.3
01#17	3.0	3.0	3.0	2.8	2.8	2.8	3.3	3.3	3.3	3.6	3.3	3.3
01#20	3.6	3.6	3.7	3.8	3.6	3.6	3.8	3.6	3.6	3.6	3.8	3.8
02#02	3.2	3.2	3.5	3.8	3.8	3.8	3.6	3.8	3.8	3.0	4.0	3.8
02#07	2.8	2.8	4.3	3.6	3.6	3.6	4.0	3.3	3.6	3.3	4.3	3.6
02#10	3.2	3.2	3.0	3.0	2.5	2.8	3.3	3.3	3.6	1.4	3.5	3.3
02#11	3.6	3.6	3.0	3.0	2.8	2.8	3.5	3.0	3.3	1.5	3.0	3.0
02#14	3.6	3.6	3.0	3.6	3.6	3.6	3.3	3.3	3.3	2.7	3.5	3.3
02#20	4.2	4.2	3.7	3.8	3.6	3.6	3.8	3.6	3.6	2.3	3.5	3.6
03#02	3.6	3.6	3.7	4.0	3.4	3.4	3.7	3.4	3.4	3.3	3.4	3.4
03#03	3.2	3.2	3.4	2.7	2.7	2.7	2.7	2.7	3.2	3.2	3.2	2.7
03#05	2.6	2.6	3.4	3.0	3.2	3.2	3.4	3.4	3.4	2.4	3.2	3.0
03#07	4.2	4.2	4.2	3.8	3.2	3.2	3.7	2.7	3.4	3.2	2.7	2.7
03#09	3.0	3.0	3.5	3.8	3.0	3.0	3.8	3.7	3.7	2.7	2.7	2.7
03#12	2.6	2.6	2.7	2.4	2.4	2.4	2.4	2.4	2.4	2.0	2.2	2.5
03#13	2.2	2.2	1.7	2.7	1.8	2.7	2.7	2.7	2.7	1.7	2.5	2.3
03#14	4.2	4.2	2.7	3.0	3.0	3.0	3.2	3.2	3.2	2.7	3.2	3.0
03#17	3.2	3.2	3.5	3.3	2.7	2.7	3.5	3.2	3.2	3.5	3.4	3.2
04#04	2.2	2.2	3.4	3.0	2.3	2.5	3.2	3.2	3.2	3.0	3.0	2.5
04#16	2.0	2.0	3.7	3.0	2.0	1.7	2.4	2.4	2.4	3.0	2.0	1.7
04#18	1.4	1.4	3.4	3.3	3.3	3.3	3.7	3.5	3.7	3.3	3.5	3.5
04#21	1.4	1.4	2.8	3.2	3.2	3.2	2.8	2.8	2.8	2.8	2.5	2.3
04#23	1.4	1.4	3.4	3.0	3.0	3.0	3.0	3.0	3.0	3.3	3.0	2.6
04#24	2.6	2.6	2.7	3.0	2.5	2.7	3.0	3.0	3.0	2.0	2.6	2.6
04#26	3.0	3.0	3.4	3.0	2.5	2.5	2.7	2.5	2.5	2.5	2.0	2.0
04#32	3.0	3.0	3.4	3.3	3.0	3.0	3.2	3.2	3.2	2.7	2.5	2.3
04#40	3.0	3.0	3.4	3.3	2.6	2.8	3.2	2.8	3.2	3.2	2.5	2.5
04#41	3.8	3.8	3.7	3.3	3.3	2.5	3.5	3.5	2.7	3.2	3.3	3.3
05#01	2.8	2.8	3.0	2.8	2.3	2.5	3.0	2.7	3.0	2.7	2.6	2.3
05#02	4.0	4.0	3.4	3.3	3.0	3.2	3.4	2.7	3.2	3.2	2.8	2.8
05#03	3.6	3.6	3.7	3.6	3.6	3.6	2.7	2.7	3.0	3.8	2.8	2.5
05#05	2.2	2.2	3.4	3.3	3.3	3.3	3.3	3.0	3.0	3.0	3.0	2.8
05#10	4.0	4.0	4.0	3.6	3.3	3.3	3.5	2.7	3.5	3.3	3.3	2.6
05#12	2.8	2.8	3.4	3.3	3.3	3.3	3.0	2.7	3.0	2.5	3.3	2.6
05#13	2.4	2.4	2.7	3.0	2.2	2.4	3.0	2.5	2.4	2.5	3.3	2.6
05#16	3.4	3.4	3.4	3.3	2.8	2.8	3.6	3.3	3.0	3.7	2.6	2.8
05#18	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.5	4.5
06#03	2.6	2.6	3.4	3.0	2.0	2.2	3.0	3.0	3.0	2.8	2.7	2.7
06#04	2.8	2.8	3.4	3.2	2.8	2.5	3.0	2.8	2.8	2.8	2.7	2.7
06#05	1.4	1.4	3.4	3.0	2.6	2.5	3.4	3.4	3.4	2.3	2.7	2.7
06#06	2.2	2.2	2.7	2.7	2.3	2.5	3.0	3.0	3.0	3.0	3.0	3.0
06#09	2.4	2.4	3.4	3.3	3.0	2.7	3.5	3.0	3.0	3.0	3.2	3.2
06#13	1.2	1.2	2.7	3.0	2.3	2.5	3.0	2.7	2.7	1.5	2.7	2.5
06#14	3.4	3.4	3.2	3.0	3.0	3.0	3.0	3.0	3.2	2.5	3.0	2.7
06#15	1.4	1.4	2.7	2.7	1.7	1.7	2.7	2.7	2.7	1.5	2.0	1.7
06#17	2.4	2.4	3.2	3.0	2.6	3.0	3.0	2.8	3.0	3.0	2.5	2.8
06#20	3.2	3.4	3.4	3.0	2.6	2.7	3.0	3.0	3.0	2.3	2.7	2.7
07#01	2.2	2.2	3.0	2.7	2.0	2.2	2.8	2.5	2.5	2.2	2.2	2.2
07#02	3.2	3.2	3.4	3.0	2.8	2.8	3.0	3.0	3.0	3.0	3.0	3.0
07#05	1.4	1.4	3.4	2.8	2.5	2.5	2.7	2.7	2.7	2.7	2.5	2.2
07#07	2.8	2.8	3.2	3.2	3.0	3.0	3.0	3.0	3.0	3.2	2.8	2.8

07#10	2.8	2.8	3.0	2.7	2.2	2.2	3.0	3.0	3.0	2.5	2.6	2.3
07#11	2.8	2.8	3.2	3.0	2.5	2.2	3.0	2.8	2:8	2.0	2.5	2.5
07#12	1.8	1.8	3.2	2.8	2.2	2.2	2.8	2.8	2.8	2.0	2.6	2.3
07#14	3.2	3.2	3.0	3.0	3.2	3.0	3.0	2.8	2.8	3.3	2.6	2.6
07#15	1.0	1.0	3.0	1.7	1.7	1.7	2.3	2.0	2.0	1.2	1.7	1.2
07#20	3.2	3.2	3.2	3.0	2.5	2.5	3.0	3.0	3.0	2.4	2.8	2.8
08#08	2.8	2.8	3.5	3.3	3.3	3.2	3.2	3.3	3.2	3.3	2.8	2.8
09#03	2.8	2.6	2.7	2.5	1.7	1.7	1.7	1.7	1.7	2.8	1.7	1.7
09#05	1.4	1.4	2.7	2.8	2.2	2.2	3.0	2.7	2.5	2.7	2.3	2.3
09#06	2.4	2.4	2.7	3.0	2.7	2.7	2.7	2.7	2.7	2.8	1.7	1.7
09#07	2.8	2.8	3.7	3.3	3.3	3.3	3.8	3.8	3.8	3.4	3.4	3.4
09#09	2.4	2.4	2.7	3.0	3.0	3.0	3.2	2.7	3.0	2.8	2.8	2.5
09#12	2.2	2.2	2.7	2.8	2.0	2.0	3.0	1.7	1.7	2.3	2.0	1.7
09#13	1.2	1.2	2.7	2.8	2.3	2.3	2.7	1.7	1.7	2.5	1.7	1.7
09#14	3.4	3.4	2.7	3.2	2.8	3.0	3.0	2.8	2.8	2.8	2.5	2.8
09#17	2.6	2.6	2.7	2.8	2.3	2.5	3.0	2.5	2.5	2.8	2.5	2.7
09#20	3.2	3.2	2.7	3.2	2.4	2.4	3.0	2.7	2.7	2.7	2.7	2.7
10#05	1.2	1.2	4.2	3.5	2.7	2.7	3.5	3.2	3.2	3.2	2.7	3.0
10#07	2.4	2.4	3.2	3.7	3.2	3.2	3.7	3.4	3.4	4.2	3.5	2.7
10#09	1.4	1.4	3.2	3.8	2.8	3.0	3.2	2.7	3.0	3.7	3.7	3.4
10#10	2.8	2.8	3.2	2.8	2.0	2.5	3.0	3.3	3.3	3.2	2.7	2.7
10#11	2.6	2.6	3.5	3.8	2.7	2.7	3.2	2.7	3.0	3.0	2.6	2.6
10#15	1.6	1.6	3.2	2.2	2.3	2.5	3.0	3.0	3.0	2.7	2.6	2.3
10#17	1.6	1.6	3.2	3.3	3.0	3.0	3.0	2.8	3.0	3.7	3.0	3.0
11#01	1.0	1.0	2.7	3.2	2.3	2.2	3.0	2.5	2.5	3.0	2.7	2.4
11#02	3.0	3.0	3.7	3.0	2.5	3.0	3.0	2.8	3.0	3.0	3.0	3.0
11#05	1.2	1.2	3.4	3.2	2.7	2.4	3.5	3.2	3.2	3.0	3.0	3.0
11#07	2.2	2.2	3.4	3.7	3.5	3.2	3.5	3.0	3.0	3.2	3.2	3.0
11#10	3.0	2.8	3.4	3.2	2.5	2.2	3.0	2.8	2.7	2.8	3.0	2.7
11#11	3.0	3.0	3.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.5
11#13	1.2	1.2	2.7	2.5	2.2	2.5	2.5	2.5	2.5	3.0	2.7	2.7
11#14	1.4	1.4	3.4	2.8	2.8	2.8	3.2	3.2	3.2	2.8	2.8	2.8
11#20	2.4	2.4	3.7	3.5	3.3	3.3	3.6	3.3	3.3	3.3	3.6	3.6
12#04	3.4	3.4	4.2	4.0	3.0	3.5	4.2	3.7	3.7	4.2	3.5	3.5
12#05	2.4	2.4	4.2	3.8	2.7	3.2	4.2	3.7	3.4	4.2	2.5	2.8
12#06	3.0	3.0	4.0	3.8	3.5	3.8	4.0	3.5	4.0	4.5	3.5	3.8
12#09	3.2	3.2	4.2	3.8	3.5	3.8	4.0	3.7	4.0	4.2	3.5	3.6
12#10	3.4	3.4	4.2	3.6	2.5	3.0	3.5	3.2	3.2	3.5	2.7	2.7
12#11	4.0	4.0	4.0	3.8	3.0	3.3	3.8	3.7	3.7	3.2	3.2	3.2
12#12	2.8	2.8	3.7	3.3	2.5	3.0	2.7	2.7	3.0	3.2	2.7	3.2
12#13	2.2	2.2	2.7	3.0	2.5	2.7	3.2	2.7	2.7	3.0	3.0	3.2
12#15	2.6	2.6	3.7	3.0	2.5	3.0	3.0	2.7	3.0	3.0	2.7	3.5
13#01	3.4	3.4	4.2	3.6	3.0	3.3	3.8	3.5	3.5	3.2	2.6	2.6
13#10	3.8	3.8	4.2	4.0	3.6	3.6	4.3	3.8	3.8	3.0	3.3	3.3
13#13	3.0	3.0	3.7	2.7	2.8	2.5	3.2	3.2	3.2	2.4	2.8	2.8
13#14	5.0	4.8	4.2	4.3	4.0	4.3	4.3	3.6	4.3	3.5	4.3	4.0
13#15	3.6	3.8	4.0	3.8	3.8	3.8	3.8	3.8	3.8	3.0	3.3	3.6
13#16	4.0	4.0	4.5	4.3	3.6	3.6	4.0	3.6	4.3	3.7	3.6	3.6
13#18	4.2	4.4	4.8	4.6	4.6	4.6	4.6	4.6	4.6	4.8	4.6	4.6
14#02	2.4	2.4	4.2	3.8	3.0	3.3	3.5	3.3	3.0	4.0	3.3	3.3
14#03	2.2	2.2	4.0	3.0	2.8	3.0	2.7	2.5	2.7	4.6	2.8	2.8
14#05	1.4	1.4	3.2	3.4	3.2	3.2	3.5	3.5	3.5	3.0	2.7	3.0
14#07	3.4	3.4	4.0	3.8	3.6	3.6	3.5	3.3	3.6	4.3	3.3	3.3
14#10	2.6	2.6	3.4	3.0	2.6	3.0	3.0	3.0	3.0	3.0	2.8	2.8
14#13	1.8	1.8	3.4	3.2	2.8	3.0	3.0	2.7	3.0	2.7	3.0	3.0
14#14	3.0	3.0	3.7	3.8	2.8	2.8	3.0	2.8	2.8	3.0	2.8	2.8
14#15	2.2	2.2	3.7	3.0	2.6	2.8	2.8	2.8	2.8	2.3	2.6	2.3
14#17	2.2	2.2	3.7	3.5	2.8	3.0	3.3	3.3	3.3	4.6	3.4	3.3
14#18	2.4	2.4	3.7	4.6	4.3	4.3	4.6	4.3	4.3	4.8	4.3	4.3
15#01	3.6	3.4	3.2	3.6	3.3	3.0	3.8	3.0	3.0	3.0	3.0	3.3
15#05	3.0	3.0	3.7	3.8	3.0	3.0	3.6	3.0	3.2	4.3	3.3	3.3
15#06	3.8	3.8	3.2	3.6	3.6	3.6	3.5	3.3	3.3	3.8	3.3	3.3
15#09	3.8	3.8	4.0	3.6	3.3	3.3	3.6	3.6	3.3	4.8	3.3	3.3
15#10	4.6	4.6	3.7	3.6	3.6	3.3	3.6	3.3	3.6	4.0	3.3	3.3
15#11	3.8	3.8	3.7	3.6	3.0	3.0	4.0	3.3	3.3	3.8	3.3	3.3
15#13	3.0	3.0	3.4	3.3	2.6	3.0	3.3	2.8	3.0	3.3	3.3	3.3

15#15	3.0	3.0	3.0	3.3	2.8	3.0	3.3	2.8	3.0	3.3	3.0	3.2
15#20	4.6	4.6	4.0	3.8	3.6	3.3	4.0	3.5	3.5	4.0	3.5	3.5
16#01	2.8	2.8	3.0	3.3	3.3	3.3	3.3	3.3	3.3	2.7	2.8	2.3
16#02	3.2	3.2	3.7	3.8	3.6	3.6	3.3	3.3	3.5	3.5	3.3	3.3
16#03	2.6	2.6	3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.3	2.8	2.6
16#04	3.0	3.0	3.5	2.8	2.8	3.0	3.5	3.0	3.4	3.3	3.0	2.5
16#05	1.4	1.4	3.2	2.8	2.7	2.7	3.0	3.0	3.2	3.0	2.8	2.3
16#10	3.2	3.2	2.7	3.0	2.7	2.7	3.2	3.2	3.2	2.4	2.5	2.5
16#11	3.4	3.4	2.7	3.0	2.8	3.0	3.7	3.5	3.5	2.2	3.0	2.7
16#12	2.4	2.4	3.2	3.0	2.7	2.7	3.0	2.7	3.0	2.2	2.7	2.7
16#16	3.0	3.0	3.5	3.5	3.3	3.3	3.5	3.5	3.3	3.0	3.3	3.3
16#18	2.8	2.8	4.5	4.3	3.8	3.8	4.5	4.5	4.5	4.6	4.8	4.8
17#01	3.2	3.2	3.0	3.0	2.8	3.0	3.3	3.3	3.6	2.2	2.8	2.8
17#02	3.4	3.4	4.2	3.0	3.0	3.0	3.3	3.3	3.3	3.0	3.3	3.0
17#03	3.6	3.6	3.7	3.3	2.6	3.3	3.3	3.3	3.6	3.0	3.6	3.6
17#04	3.2	3.2	3.5	3.3	3.3	3.3	4.3	4.3	4.3	3.2	4.3	4.0
17#06	3.4	3.4	3.2	3.3	3.0	3.3	3.6	3.3	3.3	3.0	3.0	3.0
17#07	3.6	3.6	4.2	3.2	3.0	3.2	4.0	3.5	3.5	3.5	3.3	3.3
17#09	2.8	2.8	3.7	3.4	3.0	2.7	3.7	3.3	3.3	3.5	3.3	3.3
17#13	2.4	2.4	3.2	2.8	2.6	2.5	3.0	2.8	2.8	1.7	2.8	2.5
17#14	3.8	3.8	3.2	3.0	2.8	2.7	3.3	3.3	3.3	3.0	3.3	3.3
17#15	2.4	2.4	3.4	2.6	2.6	2.3	2.8	2.8	2.8	2.5	2.8	2.8
17#17	2.8	2.8	3.7	3.3	3.0	3.3	3.6	3.3	3.0	3.0	3.0	3.0
18#02	2.0	2.0	2.2	2.7	2.0	2.4	3.0	2.5	2.7	1.7	2.5	2.5
18#03	1.2	1.2	1.2	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
18#04	2.2	2.2	2.2	2.8	2.3	2.5	3.0	2.5	2.5	1.5	1.7	1.7
18#05	1.2	1.2	2.0	2.2	1.4	1.4	2.2	1.7	1.7	1.5	2.0	1.7
18#06	1.4	1.4	2.2	3.0	2.0	2.2	2.7	1.7	1.7	2.6	2.3	2.1
18#07	2.6	2.6	3.0	3.0	3.0	2.7	3.0	3.0	3.0	1.7	2.8	2.8
18#10	2.0	2.0	2.2	2.8	2.3	2.2	2.8	2.3	2.2	1.5	2.5	2.5
18#15	1.0	1.0	2.2	2.0	1.5	1.5	1.7	1.5	1.5	1.5	1.5	1.5
18#17	1.4	1.4	2.0	2.2	2.0	2.2	2.4	1.7	1.7	1.7	2.0	1.7
18#18	2.8	2.8	3.0	3.0	2.8	3.0	3.0	3.0	3.0	3.2	2.8	2.8
20#01	2.4	2.4	2.7	2.8	2.8	2.3	3.0	2.8	2.8	3.0	2.3	2.3
20#02	3.2	3.2	3.7	3.2	2.6	2.8	3.0	2.8	2.8	3.5	2.6	2.3
20#03	2.6	2.6	3.4	2.8	2.6	2.8	2.6	2.8	2.5	3.4	2.6	2.3
20#05	1.4	1.4	3.0	2.8	2.3	2.5	3.0	2.8	3.0	3.2	3.0	2.7
20#07	2.8	2.8	3.4	2.8	3.0	3.0	3.2	3.2	3.2	3.5	3.2	3.2
20#09	2.8	2.8	3.4	3.2	2.8	3.0	3.2	3.0	3.0	3.2	3.0	3.0
20#10	3.2	3.2	3.2	2.8	2.8	3.0	2.8	3.0	3.0	3.0	3.0	3.0
20#11	3.4	3.4	3.0	3.0	2.5	3.0	3.0	3.0	3.0	3.0	2.8	2.6
20#13	1.4	1.4	2.7	2.8	2.8	2.8	3.0	2.5	2.7	3.0	2.6	2.3
20#20	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.7
21#21	3.4	3.6	3.4	3.0	3.2	3.2	3.0	2.7	3.0	3.0	3.0	2.7
21#22	3.2	3.2	2.7	3.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0
21#23	3.8	3.8	4.0	3.3	3.3	3.3	3.3	3.6	3.8	3.0	3.0	3.0
21#24	4.0	4.0	3.0	3.0	2.5	3.0	3.0	3.0	3.0	2.5	2.7	3.0
21#28	3.2	3.2	2.7	3.0	2.5	3.0	3.0	2.7	2.7	2.7	2.7	2.5
21#29	3.2	3.2	3.2	3.2	2.5	3.0	3.0	3.0	3.0	2.7	2.5	2.8
21#35	3.0	3.0	3.0	3.0	2.0	2.0	3.0	2.6	2.6	2.4	2.6	2.6
21#33	3.2	3.2	3.0	3.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0	3.0
21#36	3.4	3.4	3.2	3.0	2.5	3.0	3.0	3.0	3.0	2.5	2.7	3.0
21#37	3.8	3.8	4.0	3.0	2.8	2.7	3.0	3.0	3.0	3.0	3.0	3.0
22#22	2.8	2.8	3.7	3.3	2.8	3.0	3.0	2.8	3.0	3.0	2.8	2.8
22#23	3.6	3.6	4.2	3.5	3.5	3.2	3.3	3.2	3.3	3.0	3.3	3.3
22#24	3.2	3.2	2.7	3.0	2.5	2.7	3.0	2.7	3.0	1.7	2.7	2.7
22#25	2.8	2.8	3.7	3.3	2.5	2.8	3.0	2.5	2.8	2.7	3.0	3.0
22#29	2.8	2.8	3.7	3.5	2.8	3.3	3.3	2.5	3.0	1.7	2.6	2.6
22#35	2.8	2.4	2.6	3.0	2.6	2.6	2.6	2.6	3.0	2.6	2.6	2.6
22#38	4.0	4.0	3.7	3.8	3.5	3.3	3.6	3.3	3:3	3.5	3.0	3.0
22#39	3.6	3.8	4.2	3.8	3.3	3.6	3.8	3.3	3.3	2.7	3.3	3.3
22#41	4.8	4.6	4.2	3.5	3.2	3.0	3.6	3.5	3.6	1.7	3.0	3.0
22#43	3.8	3.8	4.2	4.0	3.3	3.3	3.6	3.3	3.6	2.7	3.3	3.3
23#21	3.2	3.2	2.7	3.0	2.8	2.7	3.0	3.0	2.7	3.0	2.6	2.6
23#23	3.4	3.4	3.4	3.0	2.8	3.0	3.0	2.7	2.8	3.0	2.6	2.6
23#24	3.4	3.4	2.7	3.0	2.3	2.5	3.0	2.7	2.8	2.0	2.3	2.6

23#28	2.8	2.8	2.5	3.0	2.3	2.5	3.0	2.8	2.8	2.3	2.3	2.3
23#29	2.8	2.6	2.7	3.0	2.5	2.5	3.0	2.4	2.2	2.2	2.3	2.0
23#36	2.8	2.8	2.7	3.0	2.5	2.5	3.0	3.0	2.7	1.7	2.8	2.5
23#37	3.2	3.2	3.2	3.0	2.5	2.8	3.0	2.8	2.8	3.0	2.3	2.3
23#38	3.8	3.8	3.7	3.5	3.5	3.3	3.3	3.3	3.3	4.5	3.3	3.3
23#40	4.6	4.4	3.2	3.3	3.2	3.0	3.2	3.0	3.0	3.7	2.8	2.8
23#43	3.6	3.6	3.5	3.8	3.0	3.2	3.8	3.0	3.2	3.5	3.0	3.0
24#22	2.6	2.6	3.0	3.2	3.2	3.2	3.4	3.2	3.2	4.5	3.0	3.0
24#23	3.0	3.0	3.4	3.2	3.2	3.2	3.2	3.0	3.2	4.2	3.0	3.0
24#24	3.0	3.0	3.2	3.0	3.0	3.0	3.2	3.2	3.2	3.4	3.0	3.0
24#26	4.0	4.0	4.2	3.6	3.3	3.3	3.8	3.2	3.2	4.0	3.2	3.2
24#27	3.0	3.0	3.0	3.0	2.2	2.4	2.7	2.5	2.7	4.0	2.7	2.7
24#29	2.6	2.6	3.5	3.2	3.2	3.0	3.0	3.0	3.0	3.0	2.6	2.6
24#32	4.0	4.0	4.0	3.8	3.8	3.8	4.3	4.0	4.3	3.7	3.8	3.8
24#35	2.4	2.4	3.0	2.6	2.0	2.0	2.6	2.6	2.6	3.0	2.6	2.6
24#43	3.6	3.6	4.2	3.6	3.8	3.6	3.8	4.0	3.8	4.2	3.6	3.6
24#45	3.0	3.0	3.7	2.7	2.7	2.7	3.2	2.7	3.0	3.7	2.7	2.7
25#21	3.8	3.8	3.7	3.8	3.8	3.8	3.3	3.3	3.3	4.0	3.3	3.3
25#22	3.4	3.4	3.2	3.0	3.6	3.6	3.3	3.3	3.3	4.3	3.3	3.3
25#23	3.8	3.8	3.7	3.6	3.8	3.8	3.3	3.3	3.6	4.5	3.3	3.3
25#24	3.8	3.8	2.7	3.0	3.2	3.2	3.0	3.0	3.0	2.6	2.8	2.8
25#25	3.0	3.0	3.2	3.0	3.0	3.0	3.0	3.0	3.2	3.0	3.0	3.2
25#27	3.8	3.8	3.4	3.0	3.0	3.3	3.0	2.8	3.0	3.7	3.0	2.6
25#28	3.6	3.6	2.7	3.3	3.3	3.3	3.0	3.0	3.0	3.3	3.0	3.0
25#29	3.6	3.6	3.7	3.3	3.0	3.3	3.0	3.0	3.0	2.8	3.0	2.6
25#36	3.8	3.8	3.7	3.2	2.8	3.0	3.2	3.2	3.2	3.0	2.8	2.8
25#39	4.4	4.4	4.2	3.8	3.8	3.8	3.8	3.6	3.6	3.3	3.0	3.0
26#23	1.8	1.8	3.2	3.3	3.0	3.3	3.0	2.8	3.0	2.8	3.0	3.0
26#24	2.2	2.2	2.7	3.0	3.0	2.8	3.2	3.2	3.2	3.0	2.3	2.3
26#26	3.2	3.2	3.2	3.0	3.0	3.0	3.0	3.0	3.3	2.8	2.6	2.6
26#31	2.8	2.8	2.7	3.0	2.8	2.5	3.0	2.5	3.0	2.5	2.3	2.3
26#32	3.2	3.2	2.7	3.0	3.2	3.0	3.3	3.0	3.3	3.0	2.6	2.8
26#37	2.0	2.0	2.7	3.2	2.8	2.8	3.0	2.8	3.0	2.8	2.7	2.7
26#38	3.2	3.2	3.4	3.5	3.3	3.0	3.2	3.3	3.3	4.3	3.3	2.6
26#40	3.2	3.2	2.7	3.2	3.0	3.0	3.2	3.2	3.5	3.5	3.0	3.0
26#41	3.6	3.6	3.4	3.0	3.0	3.0	3.0	3.0	3.3	3.4	3.0	3.0
26#43	3.2	3.2	3.2	3.2	3.0	3.0	3.0	3.3	3.3	3.0	3.0	3.0
27#21	3.4	3.4	3.4	3.5	3.2	3.2	3.7	3.5	3.5	3.2	3.2	3.2
27#23	3.4	3.4	3.5	3.5	3.5	3.5	3.5	3.2	3.5	3.6	3.3	3.0
27#24	3.4	3.6	3.7	3.6	3.0	3.0	3.2	3.0	3.0	3.0	3.0	3.0
27#27	3.4	3.4	3.4	3.0	2.7	3.0	3.0	3.0	3.0	3.3	2.7	2.6
27#28	3.4	3.4	3.0	2.8	2.8	3.0	3.3	3.0	3.3	3.0	3.0	3.0
27#29	2.8	2.8	3.4	3.2	3.0	3.0	3.0	3.0	3.3	3.3	3.3	3.2
27#36	3.4	3.4	3.4	3.5	3.2	3.5	3.4	3.5	3.2	3.2	3.0	3.0
27#38	4.0	4.0	4.2	3.5	3.5	3.5	4.0	3.7	4.2	4.8	3.5	3.8
27#40	4.4	4.4	3.7	3.5	3.5	3.5	4.2	4.0	3.7	4.7	3.8	3.5
27#43	3.8	3.8	3.7	3.5	3.5	3.8	3.5	3.2	3.5	4.5	3.8	3.5
28#21	3.8	3.6	3.5	3.8	3.3	3.2	3.5	3.0	3.2	3.8	3.5	3.5
28#22	3.4	3.4	3.2	3.3	2.5	2.8	3.3	3.0	2.7	3.7	3.3	3.0
28#28	3.6	3.6	3.0	2.8	2.6	3.0	3.0	3.0	3.0	3.0	3.0	2.8
28#29	3.4	3.4	3.4	2.8	2.8	3.0	3.0	3.0	2.8	3.2	3.0	3.0
28#31	4.8	4.6	3.0	3.0	2.5	3.0	3.0	3.0	3.0	2.7	3.0	3.0
28#35	3.0	2.6	3.0	3.0	2.6	2.6	3.0	3.0	3.0	3.0	3.0	2.6
28#36	3.6	3.6	3.2	3.0	2.8	3.0	3.5	3.0	3.0	3.9	3.3	3.0
28#38	4.8	4.6	4.2	3.8	3.8	3.6	4.3	3.8	3.8	4.5	3.6	3.8
28#43	5.0	4.8	4.2	4.3	3.8	3.6	4.3	3.8	3.8	4.2	3.6	3.6
28#45	3.8	3.8	3.4	3.3	2.8	3.0	3.0	3.0	3.0	3.4	3.3	3.0
29#22	3.4	3.4	3.3	3.6	3.6	3.6	3.6	3.6	3.5	3.6	3.0	2.3
29#23	4.0	4.0	4.0	3.6	3.5	3.3	3.8	3.6	3.6	3.6	3.6	3.3
29#24	3.6	3.6	3.2	3.0	2.8	3.0	3.0	3.0	3.0	2.7	3.0	3.0
29#25	3.4	3.4	3.4	3.3	2.8	2.5	3.0	2.7	2.7	3.0	3.0	2.5
29#29	3.4	3.4	3.4	3.6	2.8	2.7	3.3	3.0	3.0	3.0	3.0	3.0
29#35	3.4	3.4	3.0	3.0	2.6	2.6	3.0	2.6	3.0	3.0	3.0	2.6
29#38	4.8	4.6	4.2	3.6	3.8	3.3	3.8	3.8	3.8	4.3	3.6	3.6
29#39	3.8	3.8	4.5	3.6	3.3	3.5	3.8	3.6	3.6	3.3	3.6	3.3
29#41	4.8	4.6	4.2	3.8	3.1	3.3	4.1	3.6	3.6	3.6	3.6	3.3

29#43	4.8	4.6	4.2	3.8	3.5	3.3	3.8	3.3	3.3	3.3	3.6	3.3
30#22	2.4	2.4	2.7	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
30#23	2.6	2.6	2.7	2.8	2.8	2.8	3.0	2.8	2.8	1.7	2.5	2.8
30#24	3.2	3.2	2.7	3.0	2.5	2.5	2.7	2.5	3.0	1.4	2.3	2.3
30#29	2.6	2.6	3.2	2.8	2.6	2.8	2.5	2.5	2.5	1.7	2.6	2.3
30#30	3.2	3.2	3.4	2.8	2.8	2.8	2.8	2.8	2.8	2.6	2.8	2.6
30#31	3.4	3.4	2.7	2.8	2.6	2.8	3.0	2.8	3.0	1.7	2.6	2.6
30#32	3.8	3.8	3.2	3.0	2.8	3.0	3.0	3.0	3.0	2.0	3.0	2.8
30#35	2.4	2.4	2.0	2.0	2.0	2.0	1.4	2.0	2.0	1.0	2.6	2.6
30#38	3.4	3.4	3.7	3.0	2.6	2.8	3.3	3.3	3.3	2.8	2.8	2.8
30#43	3.6	3.6	3.4	3.3	2.8	2.8	3.2	2.8	2.8	3.0	2.8	2.6
31#26	3.8	3.8	3.7	3.8	3.5	3.5	3.7	3.7	3:7	3.7	3.5	3.5
31#30	2.8	2.8	3.7	3.6	3.6	3.6	3.8	4.0	4.0	4.3	3.8	3.8
31#31	3.2	3.2	3.2	3.0	3.0	3.0	3.4	3.2	3.2	3.0	3.2	2.7
31#32	3.6	3.6	3.7	3.5	3.5	3.3	4.3	3.5	4.3	3.3	3.7	3.7
31#38	3.4	3.4	4.5	4.3	4.3	4.3	4.3	4.3	4.3	4.5	4.3	4.3
31#39	2.8	2.8	4.5	4.3	4.0	4.3	4.3	4.0	4.0	4.5	3.6	3.6
31#40	4.2	4.2	4.5	4.5	4.5	4.3	4.3	4.5	4.3	4.8	4.8	4.8
31#41	4.4	4.4	3.7	3.8	3.6	3.6	4.3	3.8	3.8	4.3	4.3	4.3
31#43	3.4	3.4	4.2	4.3	4.5	4.3	4.3	4.3	4.3	4.3	4.3	4.3
31#45	2.8	2.8	3.7	3.8	3.3	3.3	3.6	3.6	3.6	4.1	3.6	3.5
32#22	1.4	1.4	3.0	2.5	2.3	2.5	3.0	2.8	2.8	3.2	2.8	2.6
32#23	1.6	1.6	3.4	3.0	2.7	2.2	3.0	2.8	2.8	3.0	3.0	2.6
32#24	1.4	1.4	2.7	2.8	2.5	2.8	2.8	2.5	2.5	2.7	2.6	2.3
32#26	2.8	2.8	3.2	2.7	2.7	2.8	3.0	2.8	3.0	2.7	2.6	2.6
32#30	1.4	1.4	3.4	2.7	3.0	3.0	2.7	3.0	2.7	3.7	2.5	2.6
32#31	2.6	2.6	2.7	2.2	2.0	2.2	1.7	1.7	1.7	2.2	2.0	2.0
32#32	2.8	2.8	3.4	2.8	2.7	3.0	3.2	3.2	2.7	3.0	2.6	2.6
32#34	4.8	4.6	4.2	4.3	4.3	4.3	4.5	4.5	4.5	3.7	3.8	3.8
32#40	2.8	2.8	3.4	3.3	3.0	3.3	3.5	3.5	3.2	3.5	3.3	3.3
32#41	3.6	3.6	3.4	3.0	3.3	3.3	3.5	3.5	3.2	3.3	3.0	3.0
33#21	4.6	4.4	4.2	3.5	3.5	3.5	3.7	4.0	4.0	3.6	3.7	3.7
33#22	3.6	3.6	3.7	3.5	3.8	3.8	3.7	3.7	4.0	4.2	3.6	3.5
33#23	4.8	4.6	3.4	3.5	3.2	3.2	3.4	3.4	3.7	3.7	3.5	3.7
33#24	4.8	4.6	3.7	3.6	3.3	3.3	3.8	3.8	3.5	3.3	3.3	3.3
33#28	4.8	4.6	3.5	3.2	3.2	3.0	3.4	3.2	3.5	3.0	3.0	3.0
33#29	3.8	3.6	4.2	3.3	3.6	3.6	3.3	3.6	3.6	2.8	3.3	2.6
33#33	3.8	3.8	3.4	3.0	3.0	3.0	3.5	3.5	3.7	3.2	3.0	3.0
33#35	3.6	3.6	3.4	3.4	3.0	3.0	3.4	3.0	3.4	3.0	3.0	2.6
33#36	4.8	4.6	3.7	3.5	3.5	3.6	3.0	3.6	3.3	3.0	3.0	3.0
33#39	4.8	4.6	4.4	3.5	3.5	3.5	3.7	3.7	3.7	3.7	3.3	3.3
34#34	3.0	3.0	3.2	3.0	2.8	3.0	3.3	2.8	2.8	3.0	3.0	2.8
34#08	1.4	1.4	2.7	3.2	3.3	3.6	3.6	3.3	3.3	3.3	3.3	3.3
35#21	4.2	4.2	3.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
35#22	3.6	3.2	3.0	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
35#23	4.2	4.2	4.0	4.0	4.4	4.4	4.0	4.0	4.0	5.0	4.0	4.0
35#24	4.6	4.2	3.6	4.0	4.0	3.6	4.0	4.0	4.0	3.0	4.0	4.0
35#25	3.2	3.2	3.0	3.4	3.0	3.0	3.4	3.0	3.4	3.4	3.4	3.4
35#28	3.2	3.2	3.0	3.0	2.6	2.6	3.0	3.0	3.0	3.0	3.0	3.0
35#29	3.6	3.6	3.6	4.0	3.6	3.6	4.0	3.6	3.6	3.0	3.6	3.6
35#35	3.2	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.6
35#36	4.2	4.2	3.0	3.4	3.0	3.0	3.4	3.4	3.4	2.0	3.0	3.0
35#45	4.2	4.2	3.4	4.0	4.0	4.0	4.0	4.0	4.0	3.4	4.0	4.0
36#21	2.8	2.8	3.2	3.6	3.3	3.0	3.3	2.8	3.0	3.3	3.0	2.8
36#22	2.8	2.8	2.7	2.5	2.5	2.7	3.0	2.5	3.0	3.0	3.0	2.7
36#23	3.6	3.6	3.7	3.3	3.3	3.3	3.3	3.3	3.3	3.0	3.3	3.3
36#24	3.8	3.6	3.0	3.0	2.5	2.7	3.0	2.7	2.7	2.7	2.7	2.7
36#28	3.4	3.4	3.0	2.5	2.5	2.5	2.7	2.5	2.5	2.7	2.5	2.3
36#29	3.2	3.2	3.2	3.0	2.7	2.7	3.0	2.7	3.0	2.7	3.0	2.7
36#35	3.0	2.6	2.6	2.6	2.4	2.0	2.6	2.6	2.6	3.0	2.6	2.6
36#36	3.4	3.6	3.0	3.0	2.7	2.5	3.0	2.5	2.7	3.0	3.0	2.7
36#38	4.8	4.8	4.8	4.3	3.8	3.6	3.8	3.6	3.6	4.3	3.6	3.6
36#39	3.6	3.4	4.0	3.8	3.5	3.5	3.8	3.4	3.7	3.3	3.2	3.0
37#22	2.8	2.8	2.7	3.3	2.4	2.4	3.0	3.0	3.0	3.7	2.7	2.8
37#23	3.4	3.4	3.2	3.3	3.0	3.0	3.0	3.0	3.0	3.2	3.0	3.0
37#24	3.2	3.2	2.7	2.8	2.6	2.8	2.8	2.8	2.8	2.6	2.6	2.3

37#29	2.4	2.2	2.7	2.8	2.5	2.7	3.0	2.5	3.0	2.6	2.8	2.3
37#30	3.2	3.4	3.4	3.3	3.0	3.0	3.0	3.0	3.0	3.5	3.0	2.8
37#31	3.6	3.6	2.4	2.8	3.0	2.8	3.3	3.3	3.3	2.6	2.5	2.3
37#35	2.0	2.0	1.6	3.0	1.6	1.6	2.6	2.0	2.0	2.0	2.0	1.6
37#37	3.2	3.2	3.0	3.0	3.0	3.0	3.3	3.0	3.0	3.4	3.0	-3.0
37#38	4.0	4.0	4.2	3.6	3.3	3.6	3.8	3.5	3.8	4.7	3.3	3.3
37#43	3.8	3.8	3.2	3.3	3.3	3.3	3.6	3.3	3.3	4.0	3.3	3.3
38#21	2.2	2.2	2.7	2.5	2.0	2.2	2.4	1.7	2.0	1.7	1.7	1.7
38#28	2.6	2.4	1.7	2.3	1.7	1.7	2.5	1.7	1.7	1.4	1.7	1.2
38#30	2.8	2.8	2.7	3.0	2.6	2.8	3.0	3.0	3.0	3.0	2.8	2.6
38#31	3.4	3.4	1.7	1.7	1.5	1.2	2.2	1.5	1:2	1.4	1.7	1.5
38#36	2.4	2.2	1.7	2.7	1.7	1.7	2.7	1.7	1.7	1.7	2.0	1.7
38#37	2.8	2.8	1.7	2.8	1.7	2.5	3.0	2.2	2.5	2.0	2.0	2.3
38#38	3.2	3.2	3.7	3.0	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
38#41	4.0	4.0	3.2	3.3	2.2	2.7	3.0	2.7	3.0	2.3	2.3	2.6
38#43	3.2	3.2	3.2	3.0	2.6	2.2	3.0	2.7	2.4	2.4	2.0	2.0
38#45	1.8	1.8	2.4	2.5	2.0	1.7	2.4	1.7	1.7	1.7	1.7	1.5
39#22	2.8	2.8	2.2	2.6	2.6	2.2	3.0	3.0	2.4	3.0	2.8	2.3
39#23	3.2	3.2	2.7	3.3	2.5	3.0	3.3	3.0	3.0	2.8	3.0	3.3
39#24	2.8	2.8	2.5	2.8	2.5	2.7	2.8	2.7	2.0	2.5	2.3	1.7
39#26	3.8	3.6	2.7	2.8	2.5	2.5	3.0	2.7	2.7	2.6	2.8	2.6
39#32	3.8	3.6	2.7	2.8	2.8	2.7	3.0	3.0	3.0	2.6	3.0	2.3
39#33	3.0	3.0	2.7	2.8	2.6	2.5	3.0	3.0	3.0	3.0	2.6	2.3
39#35	2.6	2.2	2.0	2.0	1.6	1.6	1.4	1.0	1.0	2.6	1.6	1.6
39#39	3.2	3.2	2.7	2.8	3.0	3.0	3.0	3.0	3.0	2.8	3.0	2.7
39#40	3.8	3.6	3.0	3.0	3.0	3.0	3.3	3.0	3.0	3.3	3.0	2.8
39#45	3.4	3.4	2.7	2.5	2.0	1.7	2.7	2.4	2.4	2.8	2.5	2.3
40#21	1.8	1.8	2.7	3.5	3.3	3.3	2.7	2.5	2.5	2.6	3.3	2.8
40#26	3.4	3.4	3.4	3.0	2.8	3.0	3.3	3.3	3.3	1.4	3.0	3.0
40#31	2.8	2.6	2.4	2.5	2.3	2.2	2.7	2.5	2.5	1.0	2.3	1.8
40#32	3.4	3.4	3.2	3.0	3.0	3.0	3.5	3.3	3.3	2.0	3.3	3.0
40#34	5.0	4.8	3.7	4.3	4.3	4.3	4.3	4.3	4.3	2.3	4.3	4.3
40#36	2.4	2.2	2.7	2.8	2.0	1.7	3.0	3.0	3.0	1.7	2.6	2.3
40#38	3.0	2.8	3.4	4.3	4.3	4.3	3.0	3.0	3.0	3.3	3.0	3.0
40#40	3.4	3.4	3.2	3.3	3.0	3.0	3.0	3.0	3.3	3.3	3.0	3.0
40#42	1.0	1.2	1.7	2.5	2.0	1.7	1.7	1.7	1.7	1.5	1.7	1.7
40#44	3.2	3.2	3.2	3.0	2.8	2.7	3.0	3.0	3.0	2.5	3.0	3.0
41#26	2.6	2.6	2.7	3.0	2.8	2.8	2.7	2.5	2.5	2.3	3.0	3.0
41#31	1.4	1.4	2.7	3.0	2.6	2.8	2.5	2.8	2.5	2.5	3.0	2.5
41#32	2.4	2.4	2.7	3.0	3.0	3.0	3.3	3.3	3.3	2.8	3.3	3.3
41#34	5.0	5.0	3.7	3.3	3.5	3.5	3.7	3.5	3.5	3.2	3.0	3.0
41#36	1.2	1.4	2.7	3.0	3.0	3.0	2.8	2.8	2.8	2.7	3.0	2.6
41#38	2.4	2.4	3.7	3.3	3.3	3.3	3.3	3.3	3.3	3.7	3.0	3.0
41#40	2.6	2.6	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.3	3.3
41#41	3.0	3.0	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.4	3.3	3.3
41#43	2.2	2.2	3.7	2.7	2.7	2.7	3.0	3.0	2.8	3.4	3.0	3.0
41#44	2.6	2.6	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.0	3.0
42#21	3.8	3.6	3.7	3.5	3.5	3.5	3.4	3.2	3.4	3.7	3.5	3.5
42#22	3.4	3.6	3.4	3.5	3.0	3.0	3.5	3.5	3.2	4.2	3.0	3.0
42#23	4.0	4.0	3.7	3.8	3.8	3.8	4.2	3.8	4.0	4.2	3.5	3.5
42#24	3.8	3.8	3.4	3.2	3.2	3.2	3.2	3.2	3.5	3.0	3.0	3.0
42#25	3.4	3.4	3.7	3.2	3.0	3.0	3.0	3.0	3.3	3.7	3.0	3.3
42#28	3.8	3.8	2.7	3.5	2.7	2.7	3.0	3.0	3.0	3.2	3.0	3.3
42#29	3.4	3.4	3.4	3.3	2.7	3.0	3.0	3.0	3.3	3.2	3.0	3.3
42#36	3.6	3.6	3.4	3.0	2.7	3.0	3.5	3.3	3.0	3.2	3.0	2.7
42#42	3.4	3.4	3.2	3.0	3.0	3.0	3.0	3.0	2.7	3.2	3.0	3.0
42#45	4.0	3.8	4.5	3.3	3.0	3.0	3.3	3.0	3.3	3.7	3.3	3.5
43#23	1.8	1.8	3.2	3.5	3.3	3.3	2.5	2.7	2.7	2.7	2.7	2.7
43#24	2.6	2.6	2.7	3.0	2.5	2.7	3.0	2.8	3.0	1.7	2.7	2.5
43#26	3.4	3.4	2.7	2.8	2.5	2.7	3.0	2.7	2.7	2.0	3.0	3.0
43#31	2.8	2.8	2.4	2.4	1.7	1.7	2.2	1.7	1.7	1.7	1.7	1.7
43#36	1.8	1.8	2.7	3.0	2.5	2.4	3.0	2.7	2.7	1.7	2.6	2.8
43#38	3.2	3.2	4.2	3.2	2.7	3.0	3.0	3.0	3.0	3.2	3.0	3.0
43#39	2.4	2.4	3.7	2.7	2.7	2.7	2.7	2.4	2.7	2.5	2.7	2.7
43#40	3.4	3.4	3.0	2.6	2.6	2.8	2.8	2.8	3.0	3.3	3.0	3.0
43#41	3.8	3.8	3.4	3.2	2.8	3.0	3.0	3.0	3.0	2.5	3.0	3.0

43#43	3.0	3.0	3.2	3.0	3.0	3.0	3.0	2.7	3.0	2.7	3.0	3.0
44#21	3.4	3.4	3.4	3.0	2.5	2.7	3.0	2.8	3.0	3.3	3.0	2.7
44#23	3.4	3.4	3.4	3.2	3.0	3.0	3.2	3.0	3.0	3.7	3.0	2.8
44#24	3.4	3.4	2.7	2.8	2.6	2.8	3.0	2.8	3.0	2.6	3.0	3.0
44#28	3.4	3.4	2.5	3.0	3.0	2.7	3.0	3.0	3.0	3.0	3.0	2.6
44#31	3.6	3.6	2.7	3.0	2.6	2.8	3.0	2.8	2.8	2.6	3.0	3.0
44#36	3.4	3.4	2.7	2.8	2.8	2.7	3.0	3.0	3.0	2.8	3.0	2.6
44#38	4.0	3.8	3.7	3.0	3.0	3.0	3.0	3.0	3.0	4.7	3.0	3.0
44#43	3.8	3.8	3.4	3.0	2.8	2.8	3.2	3.0	3.0	3.4	3.0	3.0
44#44	3.6	3.6	3.2	3.0	2.8	3.0	3.0	3.3	3.3	3.3	3.0	3.0
44#45	3.4	3.4	3.4	3.0	3.0	3.0	3.0	3.0	3.0	3.4	2.8	2.6
45#22	2.6	2.6	2.7	3.3	3.3	2.8	2.8	2.8	2.8	3.7	3.0	2.8
45#23	3.2	3.2	3.2	3.5	3.0	3.0	3.3	3.3	3.3	3.0	3.0	2.6
45#24	3.2	3.2	2.7	3.3	2.5	3.0	3.3	3.3	3.3	2.3	2.8	2.3
45#26	4.0	4.0	3.4	3.3	3.0	2.4	3.0	3.0	3.0	3.0	3.0	2.6
45#32	4.2	4.2	4.0	3.6	3.6	3.6	4.3	3.6	3.6	3.5	3.3	3.3
45#33	2.6	2.6	2.7	3.0	2.5	2.7	3.3	3.0	3.0	3.0	3.0	2.6
45#35	2.4	2.4	2.6	3.0	2.6	2.6	3.0	2.6	2.6	2.6	2.6	2.6
45#39	2.6	2.6	2.7	3.0	2.8	3.0	3.0	3.0	3.0	3.5	3.0	3.0
45#40	4.0	3.8	2.7	3.3	3.3	3.3	3.3	3.3	3.3	3.7	3.3	3.3
45#45	2.6	2.6	3.2	3.3	2.8	2.8	3.0	2.8	3.0	3.0	3.0	2.8
46#49	2.0	2.0	2.4	3.0	2.6	2.6	3.0	3.0	3.0	3.0	3.6	3.6
46#25	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0
46#47	1.0	1.0	2.0	2.4	2.0	1.6	2.0	2.0	2.0	2.0	1.6	1.6
46#50	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	2.6
46#46	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46#52	3.0	3.0	3.4	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46#38	4.0	3.6	4.0	3.6	3.6	3.6	4.0	3.6	3.6	4.4	3.6	3.6
46#41	4.6	4.6	4.0	3.6	3.6	3.6	4.0	4.0	4.0	3.6	3.0	3.0
46#54	4.6	4.6	4.0	4.6	4.6	4.6	4.6	4.6	4.6	3.6	4.6	4.6
46#32	4.0	4.0	3.6	4.0	3.4	3.4	4.0	3.4	3.4	4.0	4.0	4.0
47#47	3.0	2.6	3.0	3.0	3.0	3.0	3.0	2.6	2.6	2.4	3.0	2.6
47#57	3.4	3.4	3.0	4.0	3.0	3.0	3.0	3.4	3.0	4.0	4.0	3.6
47#48	2.6	2.0	3.0	2.6	2.6	2.6	3.0	2.6	2.6	3.0	2.6	2.6
47#21	4.0	4.0	4.0	4.4	5.0	4.4	5.0	5.0	5.0	4.4	4.4	4.4
47#23	5.0	5.0	4.6	5.0	4.6	4.6	5.0	5.0	5.0	4.6	5.0	5.0
47#27	4.6	4.6	3.0	3.6	3.6	4.0	3.6	4.0	3.6	4.0	4.0	4.0
47#55	3.6	3.6	3.0	4.0	3.4	3.4	3.0	3.0	3.0	4.0	3.0	3.0
47#53	5.0	4.4	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
47#59	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
47#60	5.0	5.0	4.6	5.0	5.0	5.0	5.0	5.0	5.0	4.6	5.0	5.0
48#48	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.6	3.0
48#47	3.0	3.0	3.4	4.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
48#57	3.0	3.0	3.0	4.0	4.0	4.0	3.6	4.0	3.6	4.6	4.0	3.6
48#49	3.6	3.6	3.0	4.0	3.0	3.0	3.6	3.4	3.0	3.0	4.0	4.0
48#27	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.6	4.0	4.0
48#23	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0
48#51	4.0	4.0	4.0	4.4	4.4	4.4	4.0	4.0	4.0	4.6	4.0	4.0
48#32	4.6	4.6	4.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0
48#40	5.0	5.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
48#34	5.0	5.0	4.4	5.0	5.0	5.0	5.0	5.0	5.0	4.0	5.0	5.0
49#47	1.0	1.0	2.0	2.0	2.0	1.6	2.0	1.6	2.0	2.0	1.6	1.6
49#48	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
49#57	1.4	1.4	3.4	3.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49#49	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49#25	3.0	3.0	3.4	3.6	3.6	3.6	4.0	3.6	4.0	4.0	3.6	3.6
49#33	3.4	3.0	3.0	4.6	3.6	3.6	4.0	4.0	4.0	3.6	3.6	4.0
49#42	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49#51	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0
49#53	4.6	4.6	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
49#60	5.0	5.0	3.4	4.6	4.6	4.6	4.6	4.6	4.6	3.6	4.6	4.6
50#42	2.0	2.0	2.0	2.0	1.6	1.6	2.6	1.6	1.6	3.0	2.0	1.6
50#49	2.0	2.0	2.0	2.4	1.6	1.6	2.6	1.6	1.6	2.4	2.6	1.6
50#25	3.0	2.0	3.0	3.0	2.6	2.6	3.0	3.0	3.0	3.0	2.6	2.6
50#50	3.0	2.6	3.0	3.0	2.6	2.6	3.0	2.6	2.6	3.0	3.0	2.6
50#51	3.0	3.0	3.0	3.6	3.0	3.0	3.0	3.0	3.0	3.4	3.0	3.0

50#23	3.0	3.0	3.0	4.0	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0
50#38	4.0	4.0	3.4	4.6	4.0	4.0	4.6	4.6	4.6	4.4	4.6	4.6
50#41	4.6	4.0	3.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
50#54	5.0	5.0	4.0	4.6	4.6	4.6	5.0	5.0	5.0	4.0	5.0	5.0
50#58	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51#52	2.0	2.0	2.0	2.4	1.6	1.6	2.4	2.0	2.0	2.0	1.6	1.6
51#49	2.0	2.0	3.0	2.0	1.6	1.6	3.0	2.0	2.0	1.4	1.6	1.6
51#25	2.6	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51#50	3.0	3.0	3.0	3.0	3.4	3.4	3.0	3.0	3.0	1.0	3.0	3.0
51#51	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51#23	3.4	3.4	3.0	4.0	4.0	4.0	3.6	4.0	3.6	4.0	4.0	4.0
51#38	4.0	4.0	3.4	3.6	3.6	3.6	4.0	3.6	3.6	4.6	4.0	4.0
51#40	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
51#41	4.6	4.6	3.0	3.0	3.0	3.0	4.0	4.0	4.0	3.0	4.0	4.0
51#54	4.6	4.6	4.0	5.0	4.6	4.6	5.0	5.0	5.0	3.6	5.0	5.0
52#49	2.0	2.0	2.0	2.4	1.0	1.4	2.4	1.4	1.4	1.6	1.6	1.6
52#21	3.0	3.0	3.0	4.0	3.6	3.6	3.6	3.0	3.0	3.0	3.4	3.0
52#25	3.0	2.6	3.0	3.0	2.0	2.0	3.0	3.0	3.0	3.0	2.0	2.0
52#52	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
52#55	3.0	3.0	3.0	3.0	2.4	2.4	3.0	3.0	3.0	3.0	3.0	3.0
52#50	3.0	3.0	2.0	2.4	2.0	2.0	3.0	2.0	2.4	1.0	2.4	2.0
52#53	4.0	3.6	4.0	4.0	3.6	4.0	4.0	4.0	4.0	3.0	4.0	3.6
52#54	4.6	4.6	4.0	4.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
52#59	4.0	4.0	3.0	3.4	3.4	3.4	3.4	3.0	3.0	3.0	3.4	3.4
52#41	4.6	4.6	4.0	4.0	3.6	3.6	4.0	4.0	4.0	3.0	4.0	4.0
53#21	2.0	1.6	2.4	2.4	2.0	2.0	2.0	1.6	2.0	3.0	2.0	2.0
53#50	1.0	1.0	2.0	2.4	1.6	1.6	2.6	1.6	1.6	1.4	1.6	1.6
53#46	1.0	1.0	2.4	2.0	1.0	1.0	2.0	1.0	1.0	2.4	1.0	1.0
53#55	1.0	1.0	2.4	2.0	1.0	1.0	2.0	1.6	1.6	3.0	1.0	1.0
53#53	3.0	2.6	3.0	3.4	3.0	3.0	3.4	3.0	3.0	3.0	3.4	3.0
53#59	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	3.0	3.4	3.0
53#43	3.0	3.0	3.0	3.0	3.0	3.0	3.6	3.0	3.0	4.6	3.6	3.0
53#60	4.0	4.0	2.6	4.0	4.0	4.0	4.0	4.0	4.0	2.0	4.0	3.6
53#54	4.6	4.6	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0
53#41	5.0	5.0	4.0	3.0	3.0	3.0	3.6	3.0	3.0	3.6	3.0	3.0
54#53	1.4	1.4	2.0	1.4	1.0	1.0	1.0	1.0	1.0	2.0	1.4	1.4
54#40	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.6	2.6	1.6	1.6
54#54	2.6	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
54#41	2.6	3.0	2.6	1.4	1.4	1.4	1.4	1.4	1.4	2.0	1.4	1.4
54#08	3.0	3.0	3.0	3.4	3.0	3.0	3.4	3.0	3.0	3.0	3.4	3.4
54#34	4.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
54#60	2.0	2.0	2.6	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	2.0
54#39	1.0	1.0	2.6	1.6	1.6	1.6	1.0	1.0	1.0	2.6	1.0	1.0
54#18	2.0	2.0	2.4	2.0	2.0	2.0	2.4	2.0	2.0	3.4	2.0	2.0
54#07	1.0	1.0	2.0	1.4	1.4	1.4	1.4	1.4	1.4	2.0	1.4	1.4
55#57	1.0	1.0	2.4	2.4	1.4	1.0	2.4	2.0	2.0	3.0	2.4	2.0
55#58	2.0	2.0	2.0	2.0	2.0	1.6	2.6	2.0	2.0	2.6	2.0	2.0
55#49	2.0	1.6	2.0	2.4	1.6	1.6	2.4	2.0	2.0	1.4	2.0	1.6
55#55	2.6	2.6	3.0	3.0	2.6	2.6	3.0	3.0	3.0	3.0	2.6	2.6
55#50	3.0	3.0	2.0	3.0	2.6	3.0	3.0	3.0	3.0	1.4	3.0	3.0
55#51	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.6	3.0	3.0
55#53	3.6	3.6	4.0	4.0	3.0	3.4	4.0	3.6	3.6	4.0	3.6	3.6
55#59	4.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0
55#40	4.0	4.0	3.0	4.0	3.6	3.6	4.0	3.6	4.0	4.6	3.6	4.0
55#54	5.0	5.0	4.0	5.0	4.0	4.4	5.0	4.6	5.0	3.6	4.6	5.0
56#49	1.0	1.0	1.4	2.0	1.6	2.0	3.0	2.0	1.6	1.6	2.0	1.6
56#51	1.6	1.6	2.4	3.0	2.6	2.6	3.0	3.0	3.0	3.0	3.0	2.6
56#52	1.6	1.6	2.4	3.0	2.4	2.4	3.0	2.0	2.4	3.0	3.0	2.6
56#56	2.6	2.6	2.4	3.0	2.6	3.0	3.0	3.0	3.0	3.0	2.6	3.0
56#43	3.0	3.0	3.0	3.6	3.0	3.0	3.6	3.0	3.0	3.0	3.0	3.0
56#38	3.0	3.0	3.4	3.6	3.6	3.6	4.0	3.6	3.6	3.6	3.6	3.6
56#43	3.6	3.6	3.0	4.0	3.6	3.6	4.0	3.6	3.6	3.0	3.6	3.6
56#40	4.0	4.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	3.4	4.0	4.0
56#41	5.0	5.0	3.4	3.6	3.6	3.6	4.0	3.6	3.6	2.4	3.6	3.6
56#54	4.6	4.6	3.0	4.6	4.0	4.0	4.6	4.6	4.6	3.0	4.6	4.6
57#47	2.6	2.6	2.0	2.4	2.0	1.6	2.0	1.6	1.6	1.0	2.0	1.6

57#48	2.0	2.0	1.4	2.0	1.6	1.6	2.0	1.6	1.6	1.4	1.6	1.6
57#57	2.6	2.6	3.0	3.0	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0
57#21	4.0	3.6	2.4	3.6	3.0	3.0	3.6	3.0	3.0	2.4	3.0	3.0
57#23	4.6	4.6	2.4	3.6	3.6	3.6	3.0	3.0	3.0	2.4	3.0	3.0
57#27	4.0	4.0	2.4	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	3.0
57#51	3.0	3.0	3.0	3.0	2.0	2.0	3.0	3.0	3.0	2.4	3.0	3.0
57#53	4.6	4.6	3.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	3.6	3.6
57#59	4.6	4.6	2.4	4.0	3.4	3.4	4.0	3.4	3.4	3.0	4.0	4.0
57#60	5.0	5.0	2.4	3.6	2.6	3.0	3.6	2.6	3.0	2.0	4.0	4.0
58#48	2.0	2.0	3.0	2.4	2.4	2.4	2.4	2.4	2.4	2.0	2.0	2.4
58#42	2.4	2.4	3.0	3.4	3.4	3.4	3.4	3.4	3.4	3.6	3.0	3.0
58#49	3.0	3.0	3.0	3.0	2.6	2.6	3.0	2.6	3.0	2.6	2.6	3.0
58#25	3.0	3.0	3.4	4.0	4.0	4.0	4.0	3.6	3.6	3.6	4.0	3.0
58#58	3.0	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
58#21	3.4	3.4	3.0	4.0	4.0	4.0	4.0	3.4	3.4	3.6	4.0	3.4
58#28	3.6	3.6	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.6	3.6	3.0
58#59	5.0	4.4	3.4	5.0	5.0	5.0	5.0	4.6	4.6	4.6	5.0	4.4
58#41	4.6	4.6	3.4	4.4	4.0	4.0	4.0	3.4	3.4	5.0	4.0	4.0
58#60	4.6	4.6	4.4	5.0	5.0	5.0	5.0	4.6	4.6	2.6	4.6	4.6
59#53	2.6	2.6	3.4	3.0	3.0	3.4	3.6	3.0	2.6	2.0	3.0	3.0
59#52	1.6	1.6	2.4	2.6	2.0	2.0	2.6	1.6	2.0	2.0	1.6	2.0
59#55	2.0	1.6	3.0	2.0	2.0	2.0	2.0	1.6	1.6	1.4	2.0	2.0
59#43	3.0	2.6	3.0	3.0	3.0	2.6	3.4	3.0	3.0	3.0	3.0	3.0
59#38	3.0	3.0	3.4	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
59#59	3.0	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
59#32	3.6	3.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.4	3.0	3.0
59#40	4.0	4.0	3.0	3.0	3.0	3.0	3.4	3.4	3.0	3.0	3.0	3.0
59#60	3.6	3.6	3.0	3.6	3.0	3.0	3.6	3.0	2.6	1.0	3.6	3.6
59#41	4.0	4.0	3.0	3.6	3.6	3.6	4.0	3.6	3.6	2.4	3.6	3.6
60#51	1.0	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	4.0	1.0	1.0
60#53	2.4	2.0	3.0	3.4	3.0	3.0	4.0	3.4	3.4	5.0	3.6	3.6
60#32	3.6	3.6	3.0	3.0	2.6	3.0	3.0	3.0	3.0	4.4	3.0	3.0
60#26	3.0	3.0	3.0	3.0	3.4	3.4	2.0	1.6	1.6	3.0	2.0	2.0
60#40	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.4	3.0
60#54	4.0	4.0	3.0	4.0	3.6	4.0	4.0	4.0	4.0	5.0	4.0	4.0
60#41	4.0	4.0	3.0	3.0	1.6	2.0	3.0	2.6	2.6	4.0	3.0	3.0
60#08	5.0	5.0	4.0	5.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
60#34	5.0	5.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
60#60	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

Appendix IV

Standard Deviation of Subjective Rating

	1.1	1.2	2.1	3.1	3.2	3.3	4.1	4.2	4.3	5.1	6.1	6.2
01#01	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.45
01#02	0.55	0.55	0.45	0.50	0.00	0.00	0.45	0.55	0.45	0.45	0.45	0.45
01#03	0.00	0.00	0.45	0.45	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
01#05	0.55	0.55	0.55	0.45	0.45	0.00	0.00	0.45	0.45	0.00	0.45	0.45
01#06	0.45	0.55	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.50	0.45	0.45
01#10	0.55	0.55	0.50	0.50	0.45	0.45	0.45	0.00	0.00	0.45	0.50	0.45
01#13	0.55	0.55	0.45	0.00	0.55	0.45	0.45	0.00	0.00	0.45	0.45	0.45
01#15	0.45	0.45	0.45	0.00	0.55	0.45	0.50	0.50	0.50	0.45	0.45	0.45
01#17	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.45
01#20	0.55	0.55	0.45	0.45	0.55	0.55	0.45	0.55	0.55	0.55	0.45	0.45
02#02	0.45	0.45	0.50	0.45	0.45	0.45	0.55	0.45	0.45	0.00	0.00	0.45
02#07	0.45	0.45	0.45	0.55	0.55	0.55	0.00	0.45	0.55	0.45	0.45	0.55
02#10	0.45	0.45	0.00	0.00	0.50	0.45	0.45	0.45	0.55	0.55	0.50	0.45
02#11	0.55	0.55	0.00	0.00	0.45	0.45	0.50	0.00	0.45	0.50	0.00	0.00
02#14	0.55	0.55	0.00	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.50	0.45
02#20	0.45	0.45	0.45	0.45	0.55	0.55	0.45	0.55	0.55	0.45	0.50	0.55
03#02	0.55	0.55	0.45	0.00	0.55	0.55	0.45	0.55	0.55	0.45	0.55	0.55
03#03	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
03#05	0.55	0.55	0.55	0.00	0.45	0.45	0.55	0.55	0.55	0.55	0.45	0.00
03#07	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.45	0.45
03#09	0.00	0.00	0.50	0.45	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45
03#12	0.55	0.55	0.45	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.45	0.50
03#13	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.45
03#14	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.00
03#17	0.45	0.45	0.50	0.45	0.45	0.45	0.50	0.45	0.45	0.50	0.55	0.45
04#04	0.45	0.45	0.55	0.00	0.45	0.50	0.45	0.45	0.45	0.00	0.00	0.50
04#16	0.00	0.00	0.45	0.00	0.00	0.45	0.55	0.55	0.55	0.00	0.00	0.45
04#18	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.50	0.45	0.45	0.50	0.50
04#21	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.45
04#23	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.55
04#24	0.55	0.55	0.45	0.00	0.50	0.45	0.00	0.00	0.00	0.00	0.55	0.55
04#26	0.00	0.00	0.55	0.00	0.50	0.50	0.45	0.50	0.50	0.50	0.00	0.00
04#32	0.00	0.00	0.55	0.45	0.00	0.00	0.45	0.45	0.45	0.45	0.50	0.45
04#40	0.00	0.00	0.55	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.50	0.50
04#41	0.45	0.45	0.45	0.45	0.45	0.50	0.50	0.50	0.45	0.45	0.45	0.45
05#01	0.45	0.45	0.00	0.45	0.45	0.50	0.00	0.45	0.00	0.45	0.55	0.45
05#02	0.00	0.00	0.55	0.45	0.00	0.45	0.55	0.45	0.45	0.45	0.45	0.45
05#03	0.55	0.55	0.45	0.55	0.55	0.55	0.45	0.45	0.00	0.45	0.45	0.50
05#05	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.45
05#10	0.00	0.00	0.00	0.55	0.45	0.45	0.50	0.45	0.50	0.45	0.45	0.55
05#12	0.45	0.45	0.55	0.45	0.45	0.45	0.00	0.45	0.00	0.50	0.45	0.55
05#13	0.55	0.55	0.45	0.00	0.45	0.55	0.00	0.50	0.55	0.50	0.45	0.55
05#16	0.55	0.55	0.55	0.45	0.45	0.45	0.55	0.45	0.00	0.45	0.55	0.45
05#18	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.50
06#03	0.55	0.55	0.55	0.00	0.00	0.45	0.00	0.00	0.00	0.45	0.45	0.45
06#04	0.45	0.45	0.55	0.45	0.45	0.50	0.00	0.45	0.45	0.45	0.45	0.45
06#05	0.55	0.55	0.55	0.00	0.55	0.50	0.55	0.55	0.55	0.45	0.45	0.45
06#06	0.45	0.45	0.45	0.45	0.45	0.50	0.00	0.00	0.00	0.00	0.00	0.00
06#09	0.55	0.55	0.55	0.45	0.00	0.45	0.50	0.00	0.00	0.00	0.45	0.45
06#13	0.45	0.45	0.45	0.00	0.45	0.50	0.00	0.45	0.45	0.50	0.45	0.50
06#14	0.55	0.55	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.50	0.00	0.45
06#15	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.00	0.45
06#17	0.55	0.55	0.45	0.00	0.55	0.00	0.00	0.45	0.00	0.00	0.50	0.45
06#20	0.45	0.55	0.55	0.00	0.55	0.45	0.00	0.00	0.00	0.45	0.45	0.45
07#01	0.45	0.45	0.00	0.45	0.00	0.45	0.45	0.50	0.50	0.45	0.45	0.45
07#02	0.45	0.45	0.55	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00
07#05	0.55	0.55	0.55	0.45	0.50	0.50	0.45	0.45	0.45	0.45	0.50	0.45
07#07	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.45
07#10	0.45	0.45	0.00	0.45	0.45	0.45	0.00	0.00	0.00	0.50	0.55	0.45
07#11	0.45	0.45	0.45	0.00	0.50	0.45	0.00	0.45	0.45	0.00	0.50	0.50

07#12	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.55	0.45
07#14	0.45	0.45	0.00	0.00	0.45	0.00	0.00	0.45	0.45	0.45	0.55	0.55
07#15	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.45
07#20	0.45	0.45	0.45	0.00	0.50	0.50	0.00	0.00	0.00	0.55	0.45	0.45
08#08	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
09#03	0.45	0.55	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
09#05	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.45	0.50	0.45	0.45	0.45
09#06	0.55	0.55	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
09#07	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.55	0.55
09#09	0.55	0.55	0.45	0.00	0.00	0.00	0.45	0.45	0.00	0.45	0.45	0.50
09#12	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.00	0.45
09#13	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.45	0.45
09#14	0.55	0.55	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.45	0.50	0.45
09#17	0.55	0.55	0.45	0.45	0.45	0.50	0.00	0.50	0.50	0.45	0.50	0.45
09#20	0.45	0.45	0.45	0.45	0.55	0.55	0.00	0.45	0.45	0.45	0.45	0.45
10#05	0.45	0.45	0.45	0.50	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.00
10#07	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.55	0.55	0.45	0.50	0.45
10#09	0.55	0.55	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.45	0.55
10#10	0.45	0.45	0.45	0.45	0.00	0.50	0.00	0.45	0.45	0.45	0.45	0.45
10#11	0.55	0.55	0.50	0.45	0.45	0.45	0.45	0.45	0.00	0.00	0.55	0.55
10#15	0.55	0.55	0.45	0.45	0.45	0.50	0.00	0.00	0.00	0.45	0.55	0.45
10#17	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.45	0.00	0.00
11#01	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.50	0.50	0.00	0.45	0.55
11#02	0.00	0.00	0.45	0.00	0.50	0.00	0.00	0.45	0.00	0.00	0.00	0.00
11#05	0.45	0.45	0.55	0.45	0.45	0.55	0.50	0.45	0.45	0.00	0.00	0.00
11#07	0.45	0.45	0.55	0.45	0.50	0.45	0.50	0.00	0.00	0.45	0.45	0.00
11#10	0.00	0.45	0.55	0.45	0.50	0.45	0.00	0.45	0.45	0.45	0.00	0.45
11#11	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50
11#13	0.45	0.45	0.45	0.50	0.45	0.50	0.50	0.50	0.50	0.00	0.45	0.45
11#14	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
11#20	0.55	0.55	0.45	0.50	0.45	0.45	0.55	0.45	0.45	0.45	0.55	0.55
12#04	0.55	0.55	0.45	0.00	0.71	0.50	0.45	0.45	0.45	0.45	0.50	0.50
12#05	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.50	0.45
12#06	0.00	0.00	0.00	0.45	0.50	0.45	0.00	0.50	0.00	0.50	0.50	0.45
12#09	0.45	0.45	0.45	0.45	0.50	0.45	0.00	0.45	0.00	0.45	0.50	0.55
12#10	0.55	0.55	0.45	0.55	0.50	0.00	0.50	0.45	0.45	0.50	0.45	0.45
12#11	0.00	0.00	0.00	0.45	0.71	0.45	0.45	0.45	0.45	0.45	0.45	0.45
12#12	0.45	0.45	0.45	0.45	0.50	0.00	0.45	0.45	0.00	0.45	0.45	0.45
12#13	0.45	0.45	0.45	0.00	0.50	0.45	0.45	0.45	0.45	0.00	0.00	0.45
12#15	0.55	0.55	0.45	0.00	0.50	0.00	0.00	0.45	0.00	0.00	0.45	0.50
13#01	0.55	0.55	0.45	0.55	0.00	0.45	0.45	0.50	0.50	0.45	0.55	0.55
13#10	0.45	0.45	0.45	0.00	0.55	0.55	0.45	0.45	0.45	0.00	0.45	0.45
13#13	0.00	0.00	0.45	0.45	0.45	0.50	0.45	0.45	0.45	0.55	0.45	0.45
13#14	0.00	0.45	0.45	0.45	0.00	0.45	0.45	0.55	0.45	0.50	0.45	0.00
13#15	0.55	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.55
13#16	0.00	0.00	0.50	0.45	0.55	0.55	0.00	0.55	0.45	0.45	0.55	0.55
13#18	0.45	0.55	0.45	0.55	0.55	0.55	0.55	0.55	0.55	0.45	0.55	0.55
14#02	0.55	0.55	0.45	0.45	0.00	0.45	0.50	0.45	0.00	0.00	0.45	0.45
14#03	0.45	0.45	0.00	0.00	0.45	0.00	0.45	0.50	0.45	0.55	0.45	0.45
14#05	0.55	0.55	0.45	0.55	0.45	0.45	0.50	0.50	0.50	0.00	0.45	0.00
14#07	0.55	0.55	0.00	0.45	0.55	0.55	0.50	0.45	0.55	0.45	0.45	0.45
14#10	0.55	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.45	0.45
14#13	0.45	0.45	0.55	0.45	0.45	0.00	0.00	0.45	0.00	0.45	0.00	0.00
14#14	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.45
14#15	0.45	0.45	0.45	0.00	0.55	0.45	0.45	0.45	0.45	0.45	0.55	0.45
14#17	0.45	0.45	0.45	0.50	0.45	0.00	0.45	0.45	0.45	0.55	0.55	0.45
14#18	0.55	0.55	0.45	0.55	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.45
15#01	0.55	0.55	0.45	0.55	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.45
15#05	0.00	0.00	0.45	0.45	0.00	0.00	0.55	0.00	0.45	0.45	0.45	0.45
15#06	0.45	0.45	0.45	0.55	0.55	0.55	0.50	0.45	0.45	0.45	0.45	0.45
15#09	0.45	0.45	0.00	0.55	0.45	0.45	0.55	0.55	0.45	0.45	0.45	0.45
15#10	0.55	0.55	0.45	0.55	0.55	0.45	0.55	0.45	0.55	0.00	0.45	0.45
15#11	0.45	0.45	0.45	0.55	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.45
15#13	0.00	0.00	0.55	0.45	0.55	0.00	0.45	0.45	0.00	0.45	0.45	0.45
15#15	0.00	0.00	0.00	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.00	0.45
15#20	0.55	0.55	0.00	0.45	0.55	0.45	0.00	0.50	0.50	0.00	0.50	0.50

16#01	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
16#02	0.45	0.45	0.45	0.45	0.55	0.55	0.45	0.45	0.50	0.50	0.45	0.45
16#03	0.55	0.55	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.55
16#04	0.00	0.00	0.50	0.45	0.45	0.00	0.50	0.00	0.55	0.45	0.00	0.50
16#05	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.00	0.45	0.00	0.45	0.45
16#10	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.55	0.50	0.50
16#11	0.55	0.55	0.45	0.00	0.45	0.00	0.45	0.50	0.50	0.45	0.00	0.45
16#12	0.55	0.55	0.45	0.00	0.45	0.45	0.00	0.45	0.00	0.45	0.45	0.45
16#16	0.00	0.00	0.50	0.50	0.45	0.45	0.50	0.50	0.45	0.00	0.45	0.45
16#18	0.45	0.45	0.50	0.45	0.45	0.45	0.50	0.50	0.50	0.55	0.45	0.45
17#01	0.45	0.45	0.00	0.00	0.45	0.00	0.45	0.45	0.55	0.45	0.45	0.45
17#02	0.55	0.55	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.00	0.45	0.00
17#03	0.55	0.55	0.45	0.45	0.55	0.45	0.45	0.45	0.55	0.00	0.55	0.55
17#04	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00
17#06	0.55	0.55	0.45	0.45	0.00	0.45	0.55	0.45	0.45	0.00	0.00	0.00
17#07	0.55	0.55	0.45	0.45	0.00	0.45	0.00	0.50	0.50	0.50	0.45	0.45
17#09	0.45	0.45	0.45	0.55	0.00	0.45	0.45	0.45	0.45	0.50	0.45	0.45
17#13	0.55	0.55	0.45	0.45	0.55	0.50	0.00	0.45	0.45	0.45	0.45	0.50
17#14	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45
17#15	0.55	0.55	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.50	0.45	0.45
17#17	0.45	0.45	0.45	0.45	0.00	0.45	0.55	0.45	0.00	0.00	0.00	0.00
18#02	0.00	0.00	0.45	0.45	0.00	0.55	0.00	0.50	0.45	0.45	0.50	0.50
18#03	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
18#04	0.45	0.45	0.45	0.45	0.45	0.50	0.00	0.50	0.50	0.50	0.45	0.45
18#05	0.45	0.45	0.00	0.45	0.55	0.55	0.45	0.45	0.45	0.50	0.00	0.45
18#06	0.55	0.55	0.45	0.00	0.00	0.45	0.45	0.45	0.45	0.55	0.45	0.74
18#07	0.55	0.55	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.45	0.45	0.45
18#10	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.50	0.50
18#15	0.00	0.00	0.45	0.00	0.50	0.50	0.45	0.50	0.50	0.50	0.50	0.50
18#17	0.55	0.55	0.00	0.45	0.00	0.45	0.55	0.45	0.45	0.45	0.00	0.45
18#18	0.45	0.45	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.45
20#01	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.45
20#02	0.45	0.45	0.45	0.45	0.55	0.45	0.00	0.45	0.45	0.50	0.55	0.45
20#03	0.55	0.55	0.55	0.45	0.55	0.45	0.55	0.45	0.50	0.55	0.55	0.45
20#05	0.55	0.55	0.00	0.45	0.45	0.50	0.00	0.45	0.00	0.45	0.00	0.45
20#07	0.45	0.45	0.55	0.45	0.00	0.00	0.45	0.45	0.45	0.50	0.45	0.45
20#09	0.45	0.45	0.55	0.45	0.45	0.00	0.45	0.00	0.00	0.45	0.00	0.00
20#10	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00
20#11	0.55	0.55	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.45	0.55
20#13	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.50	0.45	0.00	0.55	0.45
20#20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45
21#21	0.55	0.55	0.55	0.00	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.45
21#22	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21#23	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.55	0.45	0.00	0.00	0.00
21#24	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.45	0.00
21#28	0.45	0.45	0.45	0.00	0.50	0.00	0.00	0.45	0.45	0.45	0.45	0.50
21#29	0.45	0.45	0.45	0.45	0.50	0.00	0.00	0.00	0.00	0.45	0.50	0.45
21#35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55
21#33	0.45	0.45	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21#36	0.55	0.55	0.45	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.45	0.00
21#37	0.45	0.45	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00
22#22	0.45	0.45	0.45	0.45	0.45	0.00	0.00	0.45	0.00	0.00	0.45	0.45
22#23	0.55	0.55	0.45	0.50	0.50	0.45	0.45	0.45	0.45	0.00	0.45	0.45
22#24	0.45	0.45	0.45	0.00	0.50	0.45	0.00	0.45	0.00	0.45	0.45	0.45
22#25	0.45	0.45	0.45	0.45	0.50	0.45	0.00	0.50	0.45	0.45	0.00	0.00
22#29	0.45	0.45	0.45	0.50	0.45	0.45	0.45	0.50	0.00	0.45	0.55	0.55
22#35	0.45	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.55	0.55
22#38	0.00	0.00	0.45	0.45	0.50	0.45	0.55	0.45	0.45	0.50	0.00	0.00
22#39	0.55	0.45	0.45	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.45
22#41	0.45	0.55	0.45	0.50	0.45	0.00	0.55	0.50	0.55	0.45	0.00	0.00
22#43	0.45	0.45	0.45	0.00	0.45	0.45	0.55	0.45	0.55	0.45	0.45	0.45
23#21	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.00	0.45	0.00	0.55	0.55
23#23	0.55	0.55	0.55	0.00	0.45	0.00	0.00	0.45	0.45	0.00	0.55	0.55
23#24	0.55	0.55	0.45	0.00	0.45	0.50	0.00	0.45	0.45	0.00	0.45	0.55
23#28	0.45	0.45	0.50	0.00	0.45	0.50	0.00	0.45	0.45	0.45	0.45	0.45
23#29	0.45	0.55	0.45	0.00	0.50	0.50	0.00	0.55	0.45	0.45	0.45	0.00

23#36	0.45	0.45	0.45	0.00	0.50	0.50	0.00	0.00	0.45	0.45	0.45	0.50
23#37	0.45	0.45	0.45	0.00	0.50	0.45	0.00	0.45	0.45	0.00	0.45	0.45
23#38	0.45	0.45	0.45	0.50	0.50	0.45	0.45	0.45	0.45	0.50	0.45	0.45
23#40	0.55	0.55	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.45	0.45	0.45
23#43	0.55	0.55	0.50	0.45	0.00	0.45	0.45	0.00	0.45	0.50	0.00	0.00
24#22	0.55	0.55	0.00	0.45	0.45	0.45	0.55	0.45	0.45	0.50	0.00	0.00
24#23	0.00	0.00	0.55	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.00
24#24	0.00	0.00	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.55	0.00	0.00
24#26	0.00	0.00	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45
24#27	0.00	0.00	0.00	0.00	0.45	0.55	0.45	0.50	0.45	0.00	0.45	0.45
24#29	0.55	0.55	0.50	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.55	0.55
24#32	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.45
24#35	0.55	0.55	0.00	0.55	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.55
24#43	0.55	0.55	0.45	0.55	0.45	0.55	0.45	0.00	0.45	0.45	0.55	0.55
24#45	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.45
25#21	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45
25#22	0.55	0.55	0.45	0.00	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45
25#23	0.45	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.55	0.50	0.45	0.45
25#24	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.00	0.00	0.55	0.45	0.45
25#25	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45
25#27	0.45	0.45	0.55	0.00	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.55
25#28	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.00
25#29	0.55	0.55	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.45	0.00	0.55
25#36	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.00	0.45	0.45
25#39	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.55	0.55	0.45	0.00	0.00
26#23	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.00
26#24	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.45	0.45
26#26	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.55	0.55
26#31	0.45	0.45	0.45	0.00	0.45	0.50	0.00	0.50	0.00	0.50	0.45	0.45
26#32	0.45	0.45	0.45	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.55	0.45
26#37	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.45	0.45	0.45
26#38	0.45	0.45	0.55	0.50	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.55
26#40	0.45	0.45	0.45	0.45	0.00	0.00	0.45	0.45	0.50	0.50	0.00	0.00
26#41	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.45	0.55	0.00	0.00
26#43	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.45	0.00	0.00	0.00
27#21	0.55	0.55	0.55	0.50	0.45	0.45	0.45	0.50	0.50	0.45	0.45	0.45
27#23	0.55	0.55	0.50	0.50	0.50	0.50	0.50	0.45	0.50	0.55	0.45	0.00
27#24	0.55	0.55	0.45	0.55	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00
27#27	0.55	0.55	0.55	0.00	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.55
27#28	0.55	0.55	0.00	0.45	0.45	0.00	0.45	0.00	0.45	0.00	0.00	0.00
27#29	0.45	0.45	0.55	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.45	0.45
27#36	0.55	0.55	0.55	0.50	0.45	0.50	0.55	0.50	0.45	0.45	0.00	0.00
27#38	0.00	0.00	0.45	0.50	0.50	0.50	0.00	0.45	0.45	0.45	0.50	0.45
27#40	0.55	0.55	0.45	0.50	0.50	0.50	0.45	0.00	0.45	0.45	0.45	0.50
27#43	0.45	0.45	0.45	0.50	0.50	0.45	0.50	0.45	0.50	0.50	0.45	0.50
28#21	0.45	0.55	0.50	0.45	0.45	0.45	0.50	0.00	0.45	0.45	0.50	0.50
28#22	0.55	0.55	0.45	0.45	0.50	0.45	0.45	0.00	0.45	0.45	0.45	0.00
28#28	0.55	0.55	0.00	0.45	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.45
28#29	0.55	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.45	0.45	0.00	0.00
28#31	0.45	0.55	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.45	0.00	0.00
28#35	0.00	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.55
28#36	0.55	0.55	0.45	0.00	0.45	0.00	0.50	0.00	0.00	0.00	0.45	0.00
28#38	0.45	0.55	0.45	0.45	0.45	0.55	0.45	0.45	0.45	0.50	0.55	0.45
28#43	0.00	0.45	0.45	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.55	0.55
28#45	0.45	0.45	0.55	0.45	0.45	0.00	0.00	0.00	0.00	0.55	0.45	0.00
29#22	0.55	0.55	0.45	0.55	0.55	0.55	0.55	0.55	0.50	0.55	0.00	0.45
29#23	0.00	0.00	0.00	0.55	0.50	0.45	0.45	0.55	0.55	0.55	0.55	0.45
29#24	0.55	0.55	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.45	0.00	0.00
29#25	0.55	0.55	0.55	0.45	0.45	0.50	0.00	0.45	0.45	0.00	0.00	0.50
29#29	0.55	0.55	0.55	0.55	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.00
29#35	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.55
29#38	0.45	0.55	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.55
29#39	0.45	0.45	0.50	0.55	0.45	0.50	0.45	0.55	0.55	0.45	0.55	0.45
29#41	0.45	0.55	0.45	0.45	0.74	0.45	0.74	0.55	0.55	0.55	0.55	0.45
29#43	0.45	0.55	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.55	0.45
30#22	0.55	0.55	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

30#23	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.50	0.45
30#24	0.45	0.45	0.45	0.00	0.50	0.50	0.45	0.50	0.00	0.55	0.45	0.45
30#29	0.55	0.55	0.45	0.45	0.55	0.45	0.50	0.50	0.50	0.45	0.55	0.45
30#30	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.55
30#31	0.55	0.55	0.45	0.45	0.55	0.45	0.00	0.45	0.00	0.45	0.55	0.55
30#32	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.45
30#35	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.55	0.55
30#38	0.55	0.55	0.45	0.00	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45
30#43	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.55
31#26	0.45	0.45	0.45	0.45	0.50	0.50	0.45	0.45	0.45	0.45	0.50	0.50
31#30	0.45	0.45	0.45	0.55	0.55	0.55	0.45	0.00	0.00	0.45	0.45	0.45
31#31	0.45	0.45	0.45	0.00	0.00	0.00	0.55	0.45	0.45	0.00	0.45	0.45
31#32	0.55	0.55	0.45	0.50	0.50	0.45	0.45	0.50	0.45	0.45	0.45	0.45
31#38	0.55	0.55	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.45	0.45
31#39	0.45	0.45	0.50	0.45	0.00	0.45	0.45	0.00	0.00	0.50	0.55	0.55
31#40	0.45	0.45	0.50	0.50	0.50	0.45	0.45	0.50	0.45	0.45	0.45	0.45
31#41	0.55	0.55	0.45	0.45	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45
31#43	0.55	0.55	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.45	0.45	0.45
31#45	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.55	0.55	0.45	0.55	0.50
32#22	0.55	0.55	0.00	0.50	0.45	0.50	0.00	0.45	0.45	0.45	0.45	0.55
32#23	0.89	0.89	0.55	0.00	0.45	0.45	0.00	0.45	0.45	0.00	0.00	0.55
32#24	0.55	0.55	0.45	0.45	0.50	0.45	0.45	0.50	0.50	0.45	0.55	0.45
32#26	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.45	0.55	0.55
32#30	0.55	0.55	0.55	0.45	0.00	0.00	0.45	0.00	0.45	0.45	0.50	0.55
32#31	0.55	0.55	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.00	0.00
32#32	0.45	0.45	0.55	0.45	0.45	0.00	0.45	0.45	0.45	0.00	0.55	0.55
32#34	0.45	0.55	0.45	0.45	0.45	0.45	0.50	0.50	0.50	0.45	0.45	0.45
32#40	0.45	0.45	0.55	0.45	0.00	0.45	0.50	0.50	0.45	0.50	0.45	0.45
32#41	0.55	0.55	0.55	0.00	0.45	0.45	0.50	0.50	0.45	0.45	0.00	0.00
33#21	0.55	0.55	0.45	0.50	0.50	0.50	0.45	0.00	0.00	0.55	0.45	0.45
33#22	0.55	0.55	0.45	0.50	0.45	0.45	0.45	0.45	0.00	0.45	0.55	0.50
33#23	0.45	0.55	0.55	0.50	0.45	0.45	0.55	0.55	0.45	0.45	0.50	0.45
33#24	0.45	0.55	0.45	0.55	0.45	0.45	0.45	0.45	0.50	0.45	0.45	0.45
33#28	0.45	0.55	0.50	0.45	0.45	0.00	0.55	0.45	0.50	0.00	0.00	0.00
33#29	0.45	0.55	0.45	0.45	0.55	0.55	0.45	0.55	0.55	0.45	0.45	0.55
33#33	0.45	0.45	0.55	0.00	0.00	0.00	0.50	0.50	0.45	0.45	0.00	0.00
33#35	0.55	0.55	0.55	0.55	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.55
33#36	0.45	0.55	0.45	0.50	0.50	0.55	0.00	0.55	0.45	0.00	0.00	0.00
33#39	0.45	0.55	0.55	0.50	0.50	0.50	0.45	0.45	0.45	0.45	0.45	0.45
34#34	0.00	0.00	0.45	0.00	0.45	0.00	0.45	0.45	0.45	0.00	0.00	0.45
34#08	0.55	0.55	0.45	0.45	0.45	0.55	0.55	0.45	0.45	0.45	0.45	0.45
35#21	0.45	0.45	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35#22	0.55	0.45	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
35#23	0.45	0.45	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
35#24	0.55	0.45	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00
35#25	0.45	0.45	0.00	0.55	0.00	0.00	0.55	0.00	0.55	0.55	0.55	0.55
35#28	0.45	0.45	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
35#29	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55
35#35	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
35#36	0.45	0.45	0.00	0.55	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.00
35#45	0.45	0.45	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
36#21	0.45	0.45	0.45	0.55	0.45	0.00	0.45	0.45	0.00	0.45	0.00	0.45
36#22	0.84	0.84	0.45	0.50	0.50	0.45	0.00	0.50	0.00	0.00	0.00	0.45
36#23	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.45
36#24	0.45	0.55	0.00	0.00	0.50	0.45	0.00	0.45	0.45	0.45	0.45	0.45
36#28	0.55	0.55	0.00	0.50	0.50	0.50	0.45	0.50	0.50	0.45	0.50	0.45
36#29	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.45	0.00	0.45	0.00	0.45
36#35	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.00	0.55	0.55
36#36	0.55	0.55	0.00	0.00	0.45	0.50	0.00	0.50	0.45	0.00	0.00	0.45
36#38	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.55	0.55	0.45	0.55	0.55
36#39	0.55	0.55	0.00	0.45	0.50	0.50	0.45	0.55	0.45	0.45	0.45	0.00
37#22	0.45	0.45	0.45	0.45	0.55	0.55	0.00	0.00	0.00	0.45	0.45	0.45
37#23	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00
37#24	0.45	0.45	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.55	0.55	0.45
37#29	0.55	0.45	0.45	0.45	0.50	0.45	0.00	0.50	0.00	0.55	0.45	0.45
37#30	0.45	0.55	0.55	0.45	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.45

37#31	0.55	0.55	0.55	0.45	0.00	0.45	0.45	0.45	0.45	0.55	0.50	0.45
37#35	0.00	0.00	0.55	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.55
37#37	0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.55	0.00	0.00
37#38	0.00	0.00	0.45	0.55	0.45	0.55	0.45	0.50	0.45	0.45	0.45	0.45
37#43	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.45	0.00	0.45	0.45
38#21	0.45	0.45	0.45	0.50	0.00	0.45	0.55	0.45	0.00	0.45	0.45	0.45
38#28	0.55	0.55	0.45	0.45	0.45	0.45	0.50	0.45	0.45	0.55	0.45	0.45
38#30	0.45	0.45	0.45	0.00	0.55	0.45	0.00	0.00	0.00	0.00	0.45	0.55
38#31	0.55	0.55	0.45	0.45	0.50	0.45	0.45	0.50	0.45	0.55	0.45	0.50
38#36	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45
38#37	0.45	0.45	0.45	0.45	0.45	0.50	0.00	0.45	0.50	0.00	0.00	0.45
38#38	0.45	0.45	0.45	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
38#41	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.45	0.45	0.55
38#43	0.45	0.45	0.45	0.00	0.55	0.45	0.00	0.45	0.55	0.55	0.00	0.00
38#45	0.45	0.45	0.55	0.50	0.00	0.45	0.55	0.45	0.45	0.45	0.45	0.50
39#22	0.45	0.45	0.45	0.55	0.55	0.45	0.00	0.00	0.55	0.00	0.45	0.45
39#23	0.45	0.45	0.45	0.45	0.50	0.00	0.45	0.00	0.00	0.45	0.00	0.45
39#24	0.45	0.45	0.50	0.45	0.50	0.45	0.45	0.45	0.00	0.50	0.45	0.45
39#26	0.45	0.55	0.45	0.45	0.50	0.50	0.00	0.45	0.45	0.55	0.45	0.55
39#32	0.45	0.55	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.55	0.00	0.45
39#33	0.00	0.00	0.45	0.45	0.55	0.50	0.00	0.00	0.00	0.00	0.55	0.45
39#35	0.55	0.45	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.55	0.55	0.55
39#39	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.45
39#40	0.45	0.55	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.45
39#45	0.55	0.55	0.45	0.50	0.00	0.45	0.45	0.55	0.55	0.45	0.50	0.45
40#21	0.45	0.45	0.45	0.50	0.45	0.45	0.45	0.50	0.50	0.55	0.45	0.45
40#26	0.55	0.55	0.55	0.00	0.45	0.00	0.45	0.45	0.45	0.55	0.00	0.00
40#31	0.45	0.55	0.55	0.50	0.45	0.45	0.45	0.50	0.50	0.00	0.45	0.45
40#32	0.55	0.55	0.45	0.00	0.00	0.00	0.50	0.45	0.45	0.00	0.45	0.00
40#34	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
40#36	0.55	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.45	0.55	0.45
40#38	0.00	0.45	0.55	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.00
40#40	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.00
40#42	0.00	0.45	0.45	0.50	0.00	0.45	0.45	0.45	0.45	0.50	0.45	0.45
40#44	0.45	0.45	0.45	0.00	0.45	0.45	0.00	0.00	0.00	0.50	0.00	0.00
41#26	0.55	0.55	0.45	0.00	0.45	0.45	0.45	0.50	0.50	0.45	0.00	0.00
41#31	0.55	0.55	0.45	0.00	0.55	0.45	0.50	0.45	0.50	0.50	0.00	0.50
41#32	0.55	0.55	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45
41#34	0.00	0.00	0.45	0.45	0.50	0.50	0.45	0.50	0.50	0.45	0.00	0.00
41#36	0.45	0.55	0.45	0.00	0.00	0.00	0.45	0.45	0.45	0.45	0.00	0.55
41#38	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.00
41#40	0.55	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
41#41	0.00	0.00	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.45
41#43	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.00	0.45	0.55	0.00	0.00
41#44	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.00
42#21	0.45	0.55	0.45	0.50	0.50	0.50	0.55	0.45	0.55	0.45	0.50	0.50
42#22	0.55	0.55	0.55	0.50	0.00	0.00	0.50	0.50	0.45	0.45	0.00	0.00
42#23	0.00	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45	0.50	0.50
42#24	0.45	0.45	0.55	0.45	0.45	0.45	0.45	0.45	0.50	0.00	0.00	0.00
42#25	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.45
42#28	0.45	0.45	0.45	0.50	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.45
42#29	0.55	0.55	0.55	0.45	0.45	0.00	0.00	0.00	0.45	0.45	0.00	0.45
42#36	0.55	0.55	0.55	0.00	0.45	0.00	0.50	0.45	0.00	0.45	0.00	0.45
42#42	0.55	0.55	0.45	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.00
42#45	0.00	0.45	0.50	0.45	0.00	0.00	0.45	0.00	0.45	0.45	0.45	0.50
43#23	0.45	0.45	0.45	0.50	0.45	0.45	0.50	0.45	0.45	0.45	0.45	0.45
43#24	0.55	0.55	0.45	0.00	0.50	0.45	0.00	0.45	0.00	0.45	0.45	0.50
43#26	0.55	0.55	0.45	0.45	0.50	0.45	0.00	0.45	0.45	0.00	0.00	0.00
43#31	0.45	0.45	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
43#36	0.45	0.45	0.45	0.00	0.50	0.55	0.00	0.45	0.45	0.45	0.55	0.45
43#38	0.45	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.00	0.45	0.00	0.00
43#39	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.55	0.45	0.50	0.45	0.45
43#40	0.55	0.55	0.00	0.55	0.55	0.45	0.45	0.45	0.00	0.45	0.00	0.00
43#41	0.45	0.45	0.55	0.45	0.45	0.00	0.00	0.00	0.00	0.50	0.00	0.00
43#43	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.45	0.00	0.45	0.00	0.00
44#21	0.55	0.55	0.55	0.00	0.50	0.45	0.00	0.45	0.00	0.45	0.00	0.45

44#23	0.55	0.55	0.55	0.45	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.45
44#24	0.55	0.55	0.45	0.45	0.55	0.45	0.00	0.45	0.00	0.55	0.00	0.00
44#28	0.55	0.55	0.50	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.55
44#31	0.55	0.55	0.45	0.00	0.55	0.45	0.00	0.45	0.45	0.55	0.00	0.00
44#36	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.00	0.00	0.45	0.00	0.55
44#38	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00
44#43	0.45	0.45	0.55	0.00	0.45	0.45	0.45	0.00	0.00	0.55	0.00	0.00
44#44	0.55	0.55	0.45	0.00	0.45	0.00	0.00	0.45	0.45	0.45	0.00	0.00
44#45	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.45	0.55
45#22	0.55	0.55	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.00	0.45
45#23	0.45	0.45	0.45	0.50	0.00	0.00	0.45	0.45	0.45	0.00	0.00	0.55
45#24	0.45	0.45	0.45	0.45	0.50	0.00	0.45	0.45	0.45	0.45	0.45	0.45
45#26	0.00	0.00	0.55	0.45	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.55
45#32	0.45	0.45	0.00	0.55	0.55	0.55	0.45	0.55	0.55	0.50	0.45	0.45
45#33	0.55	0.55	0.45	0.00	0.50	0.45	0.45	0.00	0.00	0.00	0.00	0.55
45#35	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
45#39	0.55	0.55	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.50	0.00	0.00
45#40	0.00	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
45#45	0.55	0.55	0.45	0.45	0.45	0.45	0.00	0.45	0.00	0.00	0.00	0.45
46#49	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55
46#25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46#47	0.00	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.55
46#50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
46#46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46#52	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46#38	0.00	0.55	0.00	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
46#41	0.55	0.55	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
46#54	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
46#32	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.00
47#47	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.55
47#57	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.55
47#48	0.55	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55
47#21	0.00	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.00	0.55	0.55	0.55
47#23	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
47#27	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.00	0.55	0.00	0.00	0.00
47#55	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
47#53	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47#59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47#60	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
48#48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00
48#47	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48#57	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.55
48#49	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00
48#27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
48#23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48#51	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
48#32	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48#40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48#34	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#47	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.55	0.55
49#48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#57	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#25	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.00	0.00	0.55	0.55
49#33	0.55	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.55	0.00
49#42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#53	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49#60	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
50#42	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.00	0.00	0.55
50#49	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
50#25	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55
50#50	0.00	0.55	0.00	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.55
50#51	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
50#23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50#38	0.00	0.00	0.55	0.55	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55

50#41	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50#54	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
50#58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51#52	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.55
51#49	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.55	0.55	0.55
51#25	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51#50	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
51#51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51#23	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.00
51#38	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.00	0.00
51#40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51#41	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51#54	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
52#49	0.00	0.00	0.00	0.55	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55
52#21	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00
52#25	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52#52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52#55	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
52#50	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.55	0.00
52#53	0.00	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55
52#54	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52#59	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.55
52#41	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00
53#21	0.00	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00
53#50	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
53#46	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
53#55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00
53#53	0.00	0.55	0.00	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.55	0.00
53#59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00
53#43	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.55	0.00
53#60	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
53#54	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53#41	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00
54#53	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55
54#40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.55
54#54	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54#41	0.55	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.55	0.55
54#08	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.55	0.55
54#34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54#60	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54#39	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
54#18	0.00	0.00	0.55	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00
54#07	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.55	0.55
55#57	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.55	0.00
55#58	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.55	0.00	0.00
55#49	0.00	0.55	0.00	0.55	0.55	0.55	0.55	0.00	0.00	0.55	0.00	0.55
55#55	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55
55#50	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.00
55#51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
55#53	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.55	0.55
55#59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55#40	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.55	0.00	0.55	0.55	0.00
55#54	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.55	0.00	0.55	0.55	0.00
56#49	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.00	0.55	0.55	0.00	0.55
56#51	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.55
56#52	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.55	0.00	0.00	0.55
56#56	0.55	0.55	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.00
56#43	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00
56#38	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
56#43	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55
56#40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
56#41	0.00	0.00	0.55	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
56#54	0.55	0.55	0.00	0.55	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.55
57#47	0.55	0.55	0.00	0.55	0.00	0.55	0.00	0.55	0.55	0.00	0.00	0.55
57#48	0.00	0.00	0.55	0.00	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
57#57	0.55	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00

57#21	0.00	0.55	0.55	0.55	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00
57#23	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.00	0.00
57#27	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57#51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
57#53	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55
57#59	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.00
57#60	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.00	0.00
58#48	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.00	0.55
58#42	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.00	0.00
58#49	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.55	0.00	0.55	0.55	0.00
58#25	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.00
58#58	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58#21	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.55
58#28	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.00
58#59	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.55
58#41	0.55	0.55	0.55	0.55	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00
58#60	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.55	0.55
59#53	0.55	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.55	0.00	0.00	0.00
59#52	0.55	0.55	0.55	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.55	0.00
59#55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.00
59#43	0.00	0.55	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	0.00
59#38	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59#59	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59#32	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00
59#40	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00
59#60	0.55	0.55	0.00	0.55	0.00	0.00	0.55	0.00	0.55	0.00	0.55	0.55
59#41	0.00	0.00	0.00	0.55	0.55	0.55	0.00	0.55	0.55	0.55	0.55	0.55
60#51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60#53	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.55	0.55	0.00	0.55	0.55
60#32	0.55	0.55	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.55	0.00	0.00
60#26	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.55	0.55	0.00	0.00	0.00
60#40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00
60#54	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60#41	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.55	0.00	0.00	0.00
60#08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60#34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60#60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix V

Training Program of Artificial Neural Network

```
#include<stdio.h>
#include<stdlib.h>
#include<conio.h>
#include<math.h>
#define N 509 /* number of training pairs */
#define R 0.01/* learning rate */
#define M 50  /* cross checking pairs */
#define J 80   /* number of hidden units */
#define I 67   /* number of input units */
#define K 12   /* number of output units */

main()

{
float
w[J+1][K+1],v[I+1][J],detw[J+1][K+1],detv[I+1][J+1],outy[N+1][K+1],allt[N+1][K+1];
float x[I+1], y[K+1], y_in[K+1], t[K+1], det[K+1];
float z_in[J+1], z[J+1], det_in[J+1], delta[J+1], sum;
float mse_new,mse_old,mse_cn,mse_co;

int i,j,k,nn,epoch,m;
FILE *f1, *f2, *f3, *f4,*f5,*f6;

/* Step 0: Initialize weights */

for (j=0; j<=J; j++) {
        for (k=1; k<=K; k++) {
        w[j][k]=4.0/26.0*rand()/(RAND_MAX+1.0)-2.0/26.0;
        }
}

for (i=0; i<=I; i++) {
        for (j=1; j<=J; j++) {
        v[i][j]=4.0/26.0*rand()/(RAND_MAX+1.0)-2.0/26.0;
        }
}

/* initialize epoch */
epoch=0;

/* initialize mean square error */
```

```
mse_new=1000000000000;
mse_cn=1000000000000;

/* Step 1: While stopping condition is false do step 2-9 */

do {
mse_old=mse_new;
mse_new=0.0;
/* Step 2: for each training pair, do Steps 3-8 */

/* Feedforward: */

/* Each input unit (Xi, i=1,...26) receives input signal xi and */
/* and broadcast this signal to all units in the layer above */

f1=fopen("input.dat","r");
for (nn=1; nn<=N; nn++) {
        for (i=1; i<=I; i++) {
        fscanf(f1,"%f",&x[i]);
        }


//      for (k=1; k<=I; k++) {
//    printf("%d,%f\n",k,x[k]);
//      }
//      getch();
        /* Step 4. each hidden unit (Zj, j=1,...19) sums its weighted input signals */

        for (j=1; j<=J; j++) {
        sum=0;
                for (i=1; i<=I; i++) {
                sum=sum+x[i]*v[i][j];
                }
                z_in[j]=v[0][j]+sum;

                /* applying activation function */

                z[j]=1/(1+exp(-1.0*z_in[j]));
        }

        /* Step 5. Each output unit (Yk, k=1,2,...,9) sums its weighted input signals, */

        for (k=1; k<=K; k++) {
                sum=0;
                for (j=1; j<=J; j++) {
                sum=sum+z[j]*w[j][k];
```

```
        }
y_in[k]=w[0][k]+sum;
}

/* applying activation functions */

for (k=1; k<=K; k++) {
y[k]=1.0/(1.0+exp(-1.0*y_in[k]));
outy[nn][k]=y[k];
}


/* Backpropagation of error: */

/* Step 6. Each output unit (Yk, k=1,2,...9) receives a target pattern */
/*         corresponding to the input training pattern, computes its */
/*         error information */

for (k=1; k<=K; k++) {
        fscanf(f1,"%f",&t[k]);
        allt[nn][k]=t[k];
        }

for (k=1; k<=K; k++) {
det[k]=(t[k]-y[k])*y[k]*(1.0-y[k]);
}

/* calculates its weight correction term (used to update w[j][k] later */
/* and updates the weights */
for (j=1; j<=J; j++) {
        for (k=1; k<=K; k++) {
        detw[j][k]=R*det[k]*z[j];
        }
}

/* calculate its bias correction term (used to update w[0][k] later), */
/* and updates the bias */

for (k=1; k<=K; k++) {
        detw[0][k]=R*det[k];
}

/* and sends det[k] to units in the layer below. */


/* Step 7. Each hidden unit (Zj, j=1,2,...19) sums its delta */
```

```
/*                inputs from units in the layer above */

for (j=1; j<=J; j++) {
        sum=0.0;
        for (k=1; k<=K; k++) {
        sum=sum+det[k]*w[j][k];
        }
det_in[j]=sum;
}

/* multiplies by the derivatives of its activation function to*/
/* calculate its error information term,*/

for (j=1; j<=J; j++) {
delta[j]=det_in[j]*0.5*(1+z[j])*(1-z[j]);
}

/* calculates its weight correction terms (used to update v[i][j] later */

for (i=1; i<=I; i++) {
        for (j=1; j<=J; j++) {
        detv[i][j]=R*delta[j]*x[i];
        }
}

/* bias correction term */

for (j=1; j<=J; j++) {
detv[0][j]=R*delta[j];
}

/* update weights and bias:
 Step 8. Each output unit updates its bias and weights */

for (j=0; j<=J; j++) {
        for (k=1; k<=K; k++) {
        w[j][k]=w[j][k]+detw[j][k];
        }
}

/* Each hidden unit updates its bias and weights */

for (i=0; i<=I; i++) {
        for (j=1; j<=J; j++) {
        v[i][j]=v[i][j]+detv[i][j];
        }
```

```
        }

        /* update mean square error */

        for (k=1; k<=K; k++) {
        mse_new=mse_new+0.5*(t[k]-y[k])*(t[k]-y[k]);


// fprintf(f5,"%d, %f, %f\n", k, t[k], y[k]);
        }


}

/* initialize cross checking mean square error */

mse_co=mse_cn;
mse_cn=0.0;

/* cross checking */

f3=fopen("checking.dat","r");
for (m=1; m<=M; m++) {
        for (i=1; i<=I; i++) {
        fscanf(f3,"%f",&x[i]);
        }
        /* Step 4. each hidden unit (Zj, j=1,...19) sums its weighted input signals */

        for (j=1; j<=J; j++) {
        sum=0;
                for (i=1; i<=I; i++) {
                sum=sum+x[i]*v[i][j];
                }
                z_in[j]=v[0][j]+sum;

                /* applying activation function */

                z[j]=1/(1+exp(-1.0*z_in[j]));
        }

        /* Step 5. Each output unit (Yk, k=1,2,...,9) sums its weighted input signals, */

        for (k=1; k<=K; k++) {
                sum=0;
                for (j=1; j<=J; j++) {
                sum=sum+z[j]*w[j][k];
```

```
            }
        y_in[k]=w[0][k]+sum;
        }

        /* applying activation functions */

        for (k=1; k<=K; k++) {
        y[k]=1.0/(1.0+exp(-1.0*y_in[k]));
        }

        /* get taget values */

        for (k=1; k<=K; k++) {
                fscanf(f3,"%f",&t[k]);
                }
        /* update mean square error */

        for (k=1; k<=K; k++) {
        mse_cn=mse_cn+0.5*(t[k]-y[k])*(t[k]-y[k]);
        }
}
        fclose(f3);

f6=fopen("mse.dat","a+");
fprintf(f6,"%d, %f, %f\n",epoch,mse_new,mse_cn);
fclose(f6);

/* record number of epoch */
epoch++;

printf("%d, %f, %f\n",epoch,mse_new,mse_cn);

/* close training.dat file */
fclose(f1);

/* Step 9. Test stopping condition */

/* intervention */

if (mse_new>=22) {mse_cn=mse_co; mse_new=mse_old;}
} while (mse_new<=mse_old&&mse_cn<=mse_co);

f4=fopen("output.dat","w+");
for (nn=1; nn<=N; nn++) {
for (k=1; k<=K; k++) {
fprintf(f4,"%d, %d, %f, %f\n",nn,k,allt[nn][k],outy[nn][k]);
```

```
}
}
fclose(f4);
//getch();

/* record the changes of mse_new & mse_cn */



/* save weights into a file "weight.dat" */

f2=fopen("weight.dat","w+");
for (i=0; i<=I; i++) {
        for (j=1; j<=J; j++) {
        fprintf(f2,"%f\n",v[i][j]);
        }
        //fprintf(f2,"\n");
}
for (j=0; j<=J; j++) {
        for (k=1; k<=K; k++) {
        fprintf(f2,"%f\n",w[j][k]);
        }
        //fprintf(f2,"\n");
}
printf("%f\n",w[1][1]);
printf("%f\n",w[8][1]);
printf("%f\n",v[1][1]);
printf("%f\n",v[1][4]);
printf("%f\n",v[1][10]);

fclose(f2);

getch();


}
```

Appendix VI

Application Program of Artificial Neural Network

```
#include<stdio.h>
#include<stdlib.h>
#include<conio.h>
#include<math.h>
#define N 559 /* number of training pairs */
#define J 80    /* number of hidden units */
#define I 67    /* number of input units */
#define K 12   /* number of output units */

main()

{
float w[J+1][K+1],v[I+1][J],outy[N+1][K+1],allt[N+1][K+1];
float x[I+1], y[K+1], y_in[K+1], t[K+1];
float z_in[J+1], z[J+1], sum;


int i,j,k,nn;
FILE *f1, *f2, *f4;

f2=fopen("weight.dat","r");
for (i=0; i<=I; i++) {
        for (j=1; j<=J; j++) {
        fscanf(f2,"%f",&v[i][j]);
        }
}
for (j=0; j<=J; j++) {
        for (k=1; k<=K; k++) {
        fscanf(f2,"%f",&w[j][k]);
        }
}

fclose(f2);

printf("%f\n",v[0][1]);
printf("%f\n",v[0][2]);
printf("%f\n",v[0][3]);
printf("%f\n",v[0][4]);
printf("%f\n",v[0][5]);
printf("%f\n",v[0][6]);
printf("%f\n",v[0][7]);
```

```
printf("%f\n",v[0][8]);
printf("%f\n",v[0][9]);
printf("%f\n",v[0][10]);
printf("%f\n",v[1][1]);
printf("%f\n",v[1][2]);
printf("%f\n",v[1][3]);
printf("%f\n",v[1][4]);
printf("%f\n",v[1][5]);
printf("%f\n",v[1][6]);
printf("%f\n",v[1][7]);
printf("%f\n",v[1][8]);
printf("%f\n",v[1][9]);
printf("%f\n",v[1][10]);
printf("%f\n",w[0][1]);
printf("%f\n",w[1][1]);
printf("%f\n",w[2][1]);
printf("%f\n",w[3][1]);
printf("%f\n",w[4][1]);
printf("%f\n",w[5][1]);
printf("%f\n",w[6][1]);
printf("%f\n",w[7][1]);
printf("%f\n",w[8][1]);
printf("%f\n",w[9][1]);
printf("%f\n",w[10][1]);
//getch();
f1=fopen("input.dat","r");
for (nn=1; nn<=N; nn++) {
        for (i=1; i<=I; i++) {
        fscanf(f1,"%f",&x[i]);
        }


        /* Step 4. each hidden unit (Zj, j=1,...19) sums its weighted input signals */

        for (j=1; j<=J; j++) {
        sum=0;
                for (i=1; i<=I; i++) {
                sum=sum+x[i]*v[i][j];
                }
                z_in[j]=v[0][j]+sum;

                /* applying activation function */

                z[j]=1/(1+exp(-1.0*z_in[j]));
        }
```

```
/* Step 5. Each output unit (Yk, k=1,2,...,9) sums its weighted input signals, */

for (k=1; k<=K; k++) {
        sum=0;
        for (j=1; j<=J; j++) {
        sum=sum+z[j]*w[j][k];
        }
y_in[k]=w[0][k]+sum;
}

/* applying activation functions */

for (k=1; k<=K; k++) {
y[k]=1.0/(1.0+exp(-1.0*y_in[k]));
outy[nn][k]=y[k];
}


for (k=1; k<=K; k++) {
        //fscanf(f1,"%f",&t[k]);
        //allt[nn][k]=t[k];
        }

}

f4=fopen("application.dat","w+");
for (nn=1; nn<=N; nn++) {
for (k=1; k<=K; k++) {
fprintf(f4,"%d, %d, %f\n",nn,k,outy[nn][k]);
}
}
fclose(f4);
//getch();

/* save weights into a file "weight.dat" */


getch();


}→
```

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