Dynamic scanner technology, and its possible commercial effects on the textile and apparel industry.

1 Abstract

Under the banner of anthropometric studies (meaning, studies and measurements of the body), many highly scientific laboratory based projects have evolved. Researched studies into measurements the body and any other object, which needs to be measured in the third dimension, have been heavily financed by the very industries who have shown a need for virtual or digital data acquisition of a three dimensional object/subject. The purpose of this study is to compare and review contemporary technologies relating to body scanning. Then to show in greater depth an exemplary scanner system (Dynamic scanner - Faraday Lab, Glasgow University), where research is still under way. To indicate, through further personal research and experimental based capture sessions, how the progressive scanner based system could integrate accurate measurement data into the fashion industry in the future.

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Finally I would like to offer best wishes to the Dynamic/Michael Angelo Project, and hope to see the end result thrive in industry in the future.

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3 Introduction: Background study

Under the banner of anthropometric studies (meaning, studies and measurements of the body), many highly scientific laboratory based projects have evolved.
Researched studies into measurements of the body and other objects, which may need to be measured in the third dimension, have been heavily financed by the very industries who have shown a need for virtual or digital data acquisition of a three dimensional object/subject.

Many modern industries, for example textile, medical and automotive industries, have the need to model subjects in the third dimension. This desire has come about for many reasons; one is the urge to gain a virtual image for editing and marketing purposes, another reason is to save time and money realizing prototypes.
The industries using ‘virtual’ three dimensional modeling also require to gain a form of data output, for example the automotive industry requires to gain dimensional data from the model of a car for possible ergonomic design studies and general manufacture. Another example is the fashion industry this industry requires accurately measured data of a three-dimensional ‘virtual’ model for pattern cutting and manufacture.
The fashion industry’s current aim to find accurate anthropometric data has been the same for a number of years- ‘the perfect fit’, this final and ultimate aim has eluded manufactures and fashion designers alike since before the last national sizing survey in 1962.

This document further studies into anthropometric measurements and body scanners highlighted the fact that currently many consumers are unhappy with the fit of ‘high street’ bought clothing and that there is presently no ‘standardized’ sizing, a woman’s ‘size twelve’ for example, can change from store to store. Data gathered from body scanning sessions, that have already taken place US, and have begun to take place in the UK, have shown that our bodies have changed dramatically since the 1962 national survey and so therefore our body measurements have also changed. Consumers however do not assist the procedure of gaining a true 'perfect fit ', mostly consumers will not take the time to be fitted for a garment even by a trained experienced member of staff, fitting is often looked upon as an intrusion. However one can not gain a 'perfect fit' without a full anthropometric set of data, which is time consuming and intrusive to obtain.

In a report laid out by Cynthia L.Istook and Su-Jeong Hwang highlights similar difficulties of gaining 'the perfect fit' report that;

"A 1988 anthropometric survey of US Army personnel required four hours physically to landmark, measure and record the data of one subject" - (Paquette, 1996)(Istook and Hwang 2000)

The report goes on to question, " How many consumers would be willing to go through something similar?" (Istook and Hwang 2000)

Body scanning has the potential to drive the notion of the 'perfect fit' to a conclusion, which would be to give the consumer an efficient, effective system which could give accurate reproducible data without a 'four hour' measuring session.

Inspired by the merits of the Telmat, Symcad system as lectured by Ian Dewar; (director of 'CAD for CAD'), whose lecture informed on the main aims of three dimensional scanners in the fashion industry. Dewar also touched upon how many other industries were focusing in on the performance of the body scanner systems and how it was expected to adapt to the needs of the relevant industrial practices.

Further studies into body scanner systems currently being used, aside from the Telmat system, revealed a particularly innovative example of body scan technology, viz. 'the dynamic scanner.' Developed at the Faraday Institute - Glasgow University, and initially driven and funded by the innovative but progressive concept of working towards three-dimensional TV imagery, the dynamic scanner has recently been redirected into general industrial usage. The dynamic scanner can fully map an object in three dimensions in under 40 milliseconds, this fast capture rate allows moving objects to be animated into real - time' sequences.

The professors and Ph.D. students at the university are developing the dynamic scanner system and required an industry application to test the capabilities of the current technology. After many correspondences with the university they invited the author to join them in their work on taking the scanner forward. They required the technology to be put to test in a relevant scenario and the out put data/results placed into a commercial context.

The work within this study comments on the authors experimental work carried out at Glasgow University's Faraday Laboratory, but also presents a cross sectional variety of scanners and how they fundamentally differ in the manner in which they process human three - dimensional anthropometric data. This presentation will involve links into how the scanners have been used in other fields, for example: medicine; in particular how medicine and current medical research has played a supportive role in my own studies into the Faraday’s Dynamic scanner and its previous commercial data output.

Further to this, a critical and analytical set of linked experiments will be shown, go on to reveal a study into the accuracy of the output of the Faraday scanner and to maintain results at this stage of study. This information will then go forward to prove or disprove the latter part of this thesis which is ‘whether the ‘Dynamic’ scanner could give an agreeably accurate set of anthropometric data that could be readily used in the future in industry; in this instance the apparel industry’.
As an exemplary scenario to base this thesis, a backing context of measurement extraction from one concentrated area specifically the ‘human respiratory cycle’ has been chosen, the results of which will be gained from ascertaining scientific landmarked points on the torso and using these points to take accurate measurements. This then could give concluding information that could become a trigger for the apparel industry to investigate into further. This innovative study will highlight areas in which the scanner could be redefined and propose possible additional areas to be looked at in detail to gain a better commercial angle to the future research studies. All of these proposals will be taken from author’s own experience with the scanner and from information gained from the researching the fashion / textile industries needs.

Note:
All of the studies and experiments and technical tooling used within this thesis are still within a ‘work in process’ arena. Therefore the results should be taken as the first in a long line of research theses’ about the commercial scanner out - put, and so any resultant data should be looked upon in the same manner.

4 Aims and objectives

The following is a resume of the aims and objectives of this thesis. They are based on where this document is working towards with regard to the market place viz.: textile/ fashion industry. As well as including succinct aims which will inform on studies concerning a particular three - dimensional scanning/capturing technology project ‘the dynamic’ scanner based at the Faraday Laboratory - Glasgow University.

4.1 Aims

1. To look at current sources of information about digitally based scanner technologies and how they differ in practice.
2. To ascertain whether the current technology available in the Faraday Lab - University Glasgow could have commercial output that would be useful in the textile industry.
3. To realize baseline accuracy of the initial output of the Dynamic scanner and compare with current acceptable accurate margins within the apparel industry at present.
4. To accumulate accurate control data from a standard recognized measuring technique for example a simple ‘ tailors tape measure’ and produce comparably accurate results using the dynamic scanner and additional measuring software.
5. To test the sensitivity of the scanner to see if it can distinguish small movements in objects/subjects by measuring breath movements.

6. To lay foundational information for other works of this nature to be carried out in the future.
4.2 Objectives
1. Research a cross section of current technologies on the market at the moment and compare
the fundamental differences.
2. All measurements gained in the study will be accuracy tested against current accuracy
standards within the commercial fashion industry.
3. To design and practice research and development testing mainly on tailors' mannequin as a
form of controlled data, gain comparable data from 'real-life' measuring using traditional hand
measured techniques using a tailors tape and understanding the accuracy of this form of
measurement versus digital output data accuracy. Recognize the accuracy of the output and
record all data.
4. Measure a real life subject in a controlled environment; using medical breathing landmarks to
gain real life measured data. Then make comparable comments on the control data, whilst
finally making comparisons to the standard 1 cm accuracy measurement used in the fashion
industry.
5 Needs of the Textile industry
For the apparel industry, it is hoped that capturing up to date accurate, anthropometric data will
prompt the discovery of the solution to the age-old problem…garment fit!
In a recent survey by Kurt Salmon Associates;
"(KSA) 50% women and 62% of men stated that they struggled to find 'good' clothing fit."(2000)

The basis of this consumer feed back is easy to pin point, many of the pattern blocks used today
all range from the 1962 national sizing survey. Not only is this information outdated, it is also
based on the assumption that the human body is totally symmetrical, and that each person
carries him/herself in the same manner. Such problems are compounded even further, by
presumably well-meaning high-street retailers, who market what should be a UK size as a size
less than the real size supposedly in the hope that they may flatter customers into repeat buying.
Style change and life style changes do not help the problem for example fashion designers strive
for a unique cut and style which will not fit most of the more curvaceous shoppers.

Life style is another contributing factor to how the twenty first century body has changed, many
more people in today's society are much more 'body conscious' they go to the gym or exercise
more often, eat healthier and have more hectic life styles. Therefore all of this alters shape and
muscle tone so are bodies have changed and developed with our life style patterns since the last
survey in 1962. This therefore shows why there is no such thing presently as the 'perfect fit'; from
a high street outlet. And without an accurate up to date set of anthorpometric data system there
would be no way forward for the apparel industry. There would also be no way of modifying the
dimensions of the pattern blocks from the1962 national measurement survey, which form the
basis for almost all populated garment styles, and 'the standard size charts' used as a general

rule of thumb in most design houses. It is hoped that in developing a method to collate vital data, the apparel industry can begin to move forwards, and address some of the issues raised by its paying public.
The recent global economical climate has resulted in an increase in consumer spending especially in fashion, pushed along by the need to invent and reinvent our own identities through our personal appearance.

A bespoken appearance is key in today's challenging society and so it has come about that, the customized market; the tailored, designer named garments are currently not so far out of the average consumer's reach. But market research has denoted that the market wants more, more style, better fit, personalized service, in short 'MC'- Mass Customization, customized style fit and service for the masses, one definition has been taken from an American article: Paired Production, High Speed Replenishment, Supporting Technology and Mass Customization for Survival- A roadmap to the future for apparel manufacturers

MC - Mass customization is a consumer driven business strategy that uses information and manufacturing technology to efficiently produce goods with maximum differentiation and Low-cost production, and is characterized by individualized mass production.

(Staples N. -May 2001)

Lead by medical and military scientific fields of research, three-dimensional body scanners has begun to present a way out of badly fitting clothing. The big brand names in fashion have embraced the new technology available and are using it to form the platform of a total restructuring of the way we shop. The sizing survey 'Size UK' funded by a large governmental grants from trade and industries sector has began its work to recreate size charts for the whole fashion industry to work from. This survey, likened to the CAESAR survey carried out in the US last year (2000), is attempting to alter patterning sized records kept from 1962 which was the last national sizing survey. Size UK is aiming to scan 30,000 people over the coming year starting in autumn 2001.
Large names in the industry are financially backing the project for example Marks and Spencer, Monsoon, Speedo, Freeman's, Tesco, John Lewis, Oasis and many more have given time and money to this project. The amount of supporters this project has already and the amount of publicity it has produced shows that the fashion industries are realizing the importance of the consumer's feed back on what they want from the high street stores. The question is will the technology bring with it an all consuming conclusion to the perfect fit? In answer to this question, concepts like efficiency of the scanning equipment, expense and accuracy would have to be questioned and concluded upon during the length of the project.
In spite of what Size UK has to prove, the project and the technology used are proving to be the

start of something big in the plight for the 'perfect fit'.
Holding all of this survey together, from organization of volunteers and the logistics of each event all over the country is a company called '3D Electronic Center'. The following is a brief quotation about what the '3D Electronic Center' envisages gaining from Size UK…
"Fully automatic, reliable and accurate measuring and analysis systems capable of matching existing commercial hand-measuring standards;" (3D Electronic Center 2000)
The quotation above proves to be outlining aims, which are very much parallel to the aims - set for the Dynamic scanner, laid out in the beginning of this document. The text from this source goes on to inform on how the new three-dimensional measuring could be fully exploited for the future…

Additionally, in order fully to exploit this technology in a distributed manner over the Internet - for example, in new ways of interactive design and manufacturing, or to launch innovative ways of advertising and retailing - industry needs to have confidence that:
Levels of security and confidentiality can be provided those are capable of protecting their commercial interests and the privacy of their customers;
Use of such systems will be commercially and socially acceptable (3D Electronic Center 2000)

Critic and 'market - watcher' K. Chapman, a critic regularly featured online on the 'Techexchange' site (www.techexchange.com), has also given backing to this way of thinking and a few words about how she feels about the future of the commerce of fashion industry 'online' in this quote…

A recent study conducted by Gomez claimed that 45.6% of consumers surveyed would

use virtual dressing room technology if offered. E-tailers are hoping this type of personal assistance will increase consumer's trust in the products they buy online, build brand loyalty, increase shopping efficiencies, and minimize returns (Chapman K. 2000)

Despite the links with web, the fashion industry needs to concentrate on what their consumers are saying and push the standard sizing (Size UK) results into 'mass customization' as quickly as possible. However the marketing of the new scheme and the way in which the whole process is worked should be of maxim importance to the distributors. The reason for this is the way in which MC, will actually work involves 'waiting', something your average consumer does not have to deal with at the moment! Firstly the customer will have to deal with waiting to be measured, then waiting for the fabric to be individually cut to size, waiting for the whole garment to be manufactured. Then waiting to take delivery of the finished goods. This 'waiting' could prove to be a large stumbling block for the manufacturers and backers of this 'MC' new scheme. And so the companies who wish to take on the new technology and the 'MC' new shopping regime, will have to run the old way -'high street shopping' and the new MC way, parallel to each other so the consumer has choices.

Another 'obstacle' in the M C's future is exposure, many of the consumers who wish to take part in the national survey 'Size UK' will have to strip down to tight fitting clothing, for example Gym wear, lycra shorts and a tight fitting top, this is so all areas of the body are exposed to light projection and camera capturing.
However many body conscious consumers may have a few objections to stripping down to next to nothing within a public area however private it may seem. Many authorities on this subject, stress that the exposure is no more than one could experience within a changing room in a high street shop at the moment. However it is more than a consideration especially when the scanning equipment down loads accurate data of the consumers dimensions, will body conscious consumers wish to own specific accurate personal dimensions, or have them read by anyone else? From researching closely into the possible difficulties of the scanner placement into the consumer arena, many of these obstacles may be overcome with correct deployment of marketing strategies, consideration of the consumer, and a gradual development of M C into the market place.
6 Dimensional Scanning Technology: Overviewed
introduction to the current options of scanning technologies currently being used.
In the main most of the scanner-based systems currently being used to capture the three dimensional statistics of the human body use combinations of optical and illumination techniques.
The systems usually involve a varied textured illumination projected onto the body without physical contact to the body, there are one or more light sources surrounding the body and more than one capture device synced to a monitor to enable an operator to visualize the capture as its taking place. Differentiation's can be traced between many of the scanners available in the current market place the main difference being that some scanners are light based, using either strobe light or slide projection and others are laser based. Each system carries its own unique advantages and disadvantages, for example, light based systems are invariably faster at the scanning procedure section of the session, however the extraction of measurements can be quicker from a laser based scanner. To be clear which companies offer which sort of scanner system the following table informs on the different scanning technology currently available and sectionalizes it into light based and laser based products.

Table (1) is a sectioned copy of a table offered by Professors Istook and Hwang; offering tabled summaries of 3d scanners currently available:
Table 1: Istook and Hwang sectional ref: laser and light based scanning systems selection
(Istook and Hwang 2000)
Light-Based System
Product
Laser Based System
Product
Loughborough
*L A S S
Cyberware

WB4, WBX
TC 2
2T4, 3T6
Techmath
Pro Vitus, Vitus smart
Telmat
SYMCAD 3D

Turing
C3D

Wicks and Wilson
Triform,

(*Loughborough Shadow scanner.)
6.1 Light based system:
To inform further on the differences of a laser and light based system the following briefly highlights the functionality of both of the systems.
'Light-based' systems work from a projection of textured (usually pixel patterning for example guassian splash effect), which illuminates the surface of the subject or object. At the same time a system of cameras, placed around the subject gain access shots of all angles of the body.

Fig 1 - Subject within light based scanner system, shows a diagrammatic description of how a typical light based booth could be configured.
Fig 1

6.2 Laser Based Systems:
The 'Laser -based' system uses a series of laser lines which are projected horizontally across the body and deformation of the laser line offers a solid three - dimensional object present to the cameras. Moreover another difference in this process is that the subject is constantly moving, turning in fact on a rotation base. Whereas the light base system does not need to turn the subject as the cameras are placed all around the subject. Another difference between the systems is that the laser based systems uses mirrors to gain a reflective 3D form points gathering system, whereas the light based system uses surrounding cameras to show 3d form.

Plate 1: shows a photographic display of a female subject on a turntable within a laser based scanner booth. The operator is situated to the front of this image and is shown visualizing the whole process from a monitor in front of them.
Plate 1

Working along a similar theme to Prof. Istook and Hwang in their thesis '3 D Body Scanning

Systems with Application to the Apparel Industry'- published in Oct 2000. This section of the document will take a comparative look at the working systematic differences between the scanning technology on the market today and then follow with an in-depth look into the working theories of the Dynamic scanner-used to form the main body of this study.

Principal countries in the research wars for the best and fastest scanning technology can be found in Europe Japan and US. In fact initial stages and the earliest scanning system can be traced to Loughborough University in UK. This scanner was developed in the early nineties and known as LASS -(Loughborough, Anthoropometric, Shadow, Scanner).

6.3 White Light/Moiré fringe scanning based products,

6.3.1 L A S S system:

The system collated data measurements by using a rotational device, a participant stood on a circular turntable/platform, the table then rotated a full 360-degree but stopped at regular intervals, predetermined during calibration. At each stage, a sheet of light was projected vertically onto the body, passing through the center of rotation. Columns of cameras read the image of the projected light and calculated the height of the body along with the radius of the body. As a result of this, cylinders of three-dimensional surface co-ordinates were formed and over this, from an initial 315,000 of raw data points, a digital profile containing 30,000 body measurement co-ordinates were formed for each subject.

As a result of LASS the inevitable technological developments were made by other scanner research Labs, which have since progressed to the series of scanners available now. Through this primary research LASS & Loughborough University, have paved the way for the clothing industry to resize and restructure the apparel supply system to begin the revolutionary and innovative projects of the future.

6.3.2 Tc 2, (The Textile Clothing Technology Corporation)

- PMP (Phase measuring profilometry) used by TC 2 in their formation of a light based body scanner, uses light phasing techniques to gain the body measurement data. Although the techniques in the majority of areas have similarities many of the scanner systems do vary in image processing and light projection facilities, it is this differencing that sets the scanner companies apart, but the common goal, which is speed and accuracy. The following information is a brief explanation of a selection of scanner technology beginning with PMP, and the comparative differences between the scanners processing and projection/ illumination systems.

6.3.2.1 Brief Layout of how PMP/ TC2 body scanner system technically operates

The beginning of this process involves the 'set up' of the measuring distance 'standard' which is set by a triangulation of light projected from the projector unit on the baseline- (usually set at a standard mark across the subject for example base of back. Sets of CCD (Charge, Coupled, Device or digital) camera systems are then employed to capture the object/ subject. The capture point at which the subject / object is placed ready for scanning, is set from a

ratio setting at
development stage, called the calibration setting – (this is usually calculated by scanning a known
sized source for example an object often used in the fashion industry 'a tailors mannequin' from
all CCD and associating each one to its neighboring unit and the main computer).

The PMP technique uses a white light grating system, or body mapping system, which is
superimposed onto the surface of the body in a contoured pattern around the subject, which
alters by shifting in one direction, according to the subjects body structure, but is equal in the
vertical directive. Finer grating illuminated lines are used to create a more accurate scanned
image. The system phase is then shifted according to the pre-set points up and down the body.
The CCD cameras or 4 sensor cameras set within the scanner booth are then employed to
capture 4 images per CCD pod, each pod then transfers orientation points of the model / object,
all of which is transferred to the main frame to read and transpose into pixels on the screen.

The white phase model is then used to calculate three-dimensional points, which will be used to
form measurement data. At this part finer processing begins; Filtering meaning the removing of
stray points which have been taken up in the initial original raw cloud, Smoothing meaning the
smoothing over of the pixels that make up the model, revealing a higher quality of model and
removing all lower level noise. And finally compressing this is to achieve fully defined data
selection 100:1 pixels per square cm.

The phase model is then completed after the pre-processing of the 3d phase light model has
taken place, the final phase takes the model into what TC2 term 'an image twin', a virtual
reproduction of the subject / object in three- dimensions shown digitally.

Fig 2 shows example of TC2' PMP system…

Fig 2

6.3.3 Wicks and Wilson – Moiré fringing technique.
The system used by this company has been called 'Triform' (TM) this system like most of the
systems it is a non-contact surface volume capture process. It uses the Moiré Fringe techniques
which is a white light (halogen light bulb) system which strobes up and down the three-
dimensional form and where the white light stripes deform x, y, z, points are created which
eventually creates a point cloud of 400,000 points. This point cloud can be resolved into a
workable number of points (done by computer) which then creates a copy of the three-
dimensional form onto computer (image instantly look photographic) which becomes the

equivalent of 2MB a much better working model sized file. The whole process of creating a working 2MB file is done in one minute and the capturing is done in 4 seconds for a 180-degree rotation (rotation base is inside the booth). The image is captured using CCD cameras and all of the capturing is done in booth working space. The interesting element to Wicks and Wilson scanner system is the options they offer. For instance the 'Torso Scanner' this system, as the name suggests, only offers a capture view of the torso, offering a simple and cheaper version of the whole body scanner. Another option is a head scanner, this range of simple scanner systems could assist smaller companies to get involved with the three dimensional scanner systems and enable them into the market easier.

Plate2 below shows the torso scanner system.

Plate 2

6.3.4 Telmat

This system is highly tuned into gaining data that can be instantly used to pattern cut when integrated with a known CAD/CAM system -Gerber, Accumark, Lectra- Systems Modaris.
According to well documented material on Telmat system it takes the system " 1/25 of a second" (Istook and Hwang 2000) to acquire information from the model and "30 seconds for the cameras to move along the beams and acquire data from the whole body." (Istook and Hwang 2000) The system calculates upto 70 body measurements but the difference between Telmat system and that of TC2 is that the dimensional values of the body are those which conform directly with standard tailoring measurements, that is neck, bust, hip, waist, for circumferences and linear measurements of the leg and torso. Telmat use a storage system of a programmed chipped card approx. credit card sized -'Symcad body card'(TM), to give the consumer a readily available, and convenient, reference data for next time. The system works on a white light fringe basis, as does Tc2.
Plate 3 showing inside of a Telmat booth

Plate 3

6.4 Laser Based Systems:

6.4.1 Tecmath/Vitus Smart System

In comparison to the TC2 '2T4' phase light scanning technique the system from Tecmath utilizes a laser measurement method, in which the scanner projects a horizontal stripe of light onto the body of the subject. This laser line, which is eye safe and completely harmless, is reflected via an arrangement of mirrors, into one of the cameras located in each of the 4 scan head around the booth. Viewed from an angle, deformations in the diodes contained within the laser light correspond to the top section of the subject under the stripe and a measurement is given automatically. The process is then repeated around the scene, on all 4 walls, to produce three-

dimensional data for the whole body. Limitations of this system are shadowing of the body in
certain area make measuring difficult that is in the crotch area and under the armpit. The Vitus-
smart scanner system scans the subject in approx. 10 seconds then carries this information into a
3Mb workable file. All the filtering and smoothing within the scanning procedure goes on in the
initial stages of this system so everything is ready to show a full three-dimensional image on
screen within 40 seconds. The other systems have a quicker initial process but then take the time
filtering and smoothing the model later so the timings of each of the techniques are in the main
balanced against the competitions system.
Plate 4 shows subject inside a Tecmath Booth, laser systems are the tall pillars placed around the subject.

Plate 4

6.4.2 Cyberware
Working on a similar principle to the Tecmath, Vitus scanner system, the Cyberware scanner
product is more integrated, that to say it incorporates mirrors, laser and CCD cameras all in a
single molded integrated tower construction for easier construction and ease of use. The scanner
base has two of these integrated towers at either side and they move vertically whilst scanning is
in process. The scanning volume is based on a cylinder which is set at 2 m high (79”) and 1.2 m
in diameter (47”) this claims Cyberware ‘accommodates most of the human population’ for larger
subjects extras vertical tower constructions can be added. The whole scanning process takes up
to 17 seconds however the Cyberware scanners can also suffer from missing data points, hidden
by shadowing as the laser passes over the body.
Plate 5 shows a Cyberware system lasers and mirrors are placed within the yellow molded tower structures.

Plate 5

6.4.3 Stereo Photogrammetry & ‘Turing/ Faraday Dynamic scanner
The initial stages of dynamic scanner process is stereo photogrammetry a complex title but which
is a virtual copy of the way humans receive visual information everyday into the brain. The way
we view the world is through a pair of eyes each eye offering up one part of a subject/object in
variations of depth. Each eye seeing a slightly offset image, this information is then assessed by
the brain and translated into distance and form offering instant three - dimensional results. The
stereo photogrammetic process works on similar principles, however in place of eyes and a body;
twin sets of cameras are set into a tower construction, (which is termed as a pod). Each camera

views an offset version of the same object/subject this is then downloaded to an associated
computer and out onto a monitor.
Fig 3a,The first of the following diagrams shows a three-dimensional model being viewed by a coloured camera
system a little like Dynamic camera system.

Fig 3a

Fig 3b:diagram description of left and right viewing sequences in stereo photogramtic system.

Projecting random textural pixels across the subject or object assists this technique, to form a
whole image. The camera correlates a set pixel overlaid onto image, on the left to the same part
on the offset version. From this information the computer can match the various correlation's until
it obtains the whole form computed from various left and right correlation. The computer then
goes on to translate the image into a three-dimensional form by channeling the data into a three-
dimensional- software program in this case (C3d designed 'in house') this gives a visually
accepted outlet to the information stored.
Plate 6: this image shows subjects facial surface with textured projection overlaid.

Plate 6

7 Overview of the whole working and processing 'dynamic'
scans and capture system:
7.1 Calibration
Calibration of the system begins with the CCD cameras understanding the image in front of them,
then that image maybe translated to the associated computers. The process begins with a target
plate shown below in plate 10, being placed in the centre of the scanner capture arena.
Plate 10: demonstrates what a target looks like translated to digital imagery for the computer.

Plate 10

The target is then rotated in order to face each camera pod within the set. Once each camera has
viewed and captured the target plate, then the computer takes the data and processes the
information then informs on how clear black spot is to the camera. If the target spots can be
clearly viewed then the computer shows this by ringing each black spot with a red ring, as shown
in plate 10 above. If all the cameras can view the target clearly all of the various viewing
sequences that the cameras follow will come back with images of red ringed

plates. If not then
only a few of the spots will be defined with a red ring and the rest of the red rings will appear
randomly around the target and its background. After the targets are all showing correct
calibration any irrelevant data is discarded e.g. totally black viewing captures, and the file with the
target shots on is saved, ready to be correlated to the image captures of subject / objects at a
later data.

7.2 Main Overview of system
To ascertain a level of understanding of the three-dimensional dynamic scanner requires a brief
overview of the scanner process:
Four camera pods, holding a configuration of two sets of black and white cameras and 1 set of
coloured cameras- (no coloured cameras have been used in this particular research), are equally
space around the studio space. Each pod calibrated to the neighboring pod and associated to a
computer screen and drive, a customized project/strobe light system is also synched to the
pod/computer calibration.
A relevant subject/object is placed on a set point in the middle of the camera/pod arrangement.
When the capture is activated the frame grabbers within the analogue cameras are then directed
by the digital computer. A mass of digitized signals then inform the cameras to display, capture
and stop the projecting and capturing, this particular system captures 25 frames of real time
image per second which can be transcribed into 45Mb of raw data which is then downloaded onto
the computer main network.
In sync with this process, an illuminated random pixel texture - (in the form of Guassian splash a
computer created patterning which consists of random pixels), is projected over the surface of the
subject/object to create the basis of the photogrammetry technique - see above for system
process. The motion capture of the scanned subject - making this process 'real time' is then
operated by a series of triggers at the moment of capture. (The captured subjects' twin image can
be viewed constantly throughout the capturing process by a software program - in this case the
software is called XYZT in house interface to view stereo images.)

Once the frame grabber has downloaded the captured data onto the system, the computer
automatically saves and reinterprets the data in series of negative and positive patterned pixels.
These pixels then translate into series of range maps, which are indented two-dimensional
surface maps, looking a little like a relief image of a three-dimensional object pushed into soft
metal, the range map is produced from captured calibrated images. Range maps are produced
before the whole three- dimensional model can be continued and which can then be processed
into a whole three-dimensional formed image.

Plate 7: range map image, a 2d-face form constructed by the scanned data in -putted by the CCD cameras:
Plate 7

Once the data has reached this particular point the raw data is transcribed into what is termed as
a 'VRML file'- a 30Mb file. This then becomes the three-dimensional file, which will be used to run
measurements from in this research doc. (This file is set with a 0.02mm of resolution accuracy).
Plate 8: shows the almost complete three-dimensional image computed from the scanned data, within this image the
three-dimensional structure shows through.
Plate 8

The captured information can then be built into a model using the various in house software
attachments. Once the captured image has been processed into three-dimensional like many
other systems C3D Faraday system has an in built smoothing and refining procedure. This
includes a refining tool called a marching cube, basically a smoothing object that follows thew
curvatures of the three-dimensional object and smoothes away random stray pixels, which give
the appearance of a rough edge.
A final inclusion to this particular system is a three-dimensional motion capture movie (or Real
time movie) may be produced from this interpreted data capture. Presented below is a block of
systematic visuals showing the model from moment of capture to three-dimensional

representation model-rendered photographically.
Plate 9: Shows how photographic rendering is edited to fit the three dimensional grided forms.
Plate 9

Fig 4: Systematic Dynamic Scan Procedure
Fig 4.

7.3 Testing Methodology for the Dynamic scanner
The following information/data is required to understand the quality of data created from building
models in the third dimension with the Dynamic scanner system -Faraday Laboratory, Glasgow
University. And indeed the accuracy of measurements obtained by using an additional piece of 'in
house' software.
In order to reach a satisfactory understanding of this and to meet the aims laid out earlier in this
document certain criteria has been researched. Thus setting out a clear step by step scientific
understanding of what the output measurement data means and to obtain a more realistic
understanding of accuracy.
7.4 Anthropomorphic and respiratory land-marking
To gain a set of measured data from a human breathing cycle needs to begin with landmarking
areas of importance. Areas which will give maximum differentiation between the inflation and
deflation of the torso area whilst in the process of 15 cycles per minute. Background research
lead to understanding which points within the body would stand out which circumference of the

torso would produce a standard starting point. After some initial research and discussions with Dr
A.Gadden (Ph.D.) it was decided that the best place of reference was the chest - 3rd mid rib as the skeletal structured points on the body would protrude the farthest in most
peoples breathing cycle,
The abdomen/stomach area- directly across the bellybutton that would show, in profile, as the
greatest muscle deformation area within the breathing cycle.
Note: It was discovered that there is a gender differencing found in the breathing cycles, however
in order to cover all fields of scope and to standardize the results it was decided that both
genders start with the same two landmark circumference points.
7.5 Research and development: Looking at calibration accuracy, working
process accuracy, and output accuracy
To allow an accurate measured result one must first have to understand what the baseline
accuracy of the dynamic scanner data output would be. To allow a reasonable contextual
accuracy comparable measurement within the whole of this R&D sector 1-cm- (at each side of
the form =2cm total), has been set as the standard as it complies with the textile/ fashion industry
standard.
R&D testing has been produced in order to understand whether the system as it stands is 'fit for
purpose'. Whether or not suitably accurate data can be achieved, and under what settings and
'spatio' calibration can achieve this accurate data. A specific set of criteria has been produced to
assist this research and development work and from this the criteria has been methodically tested
until a suitable level of accuracy has been produced.
7.5.1 R&D Subject testing looks at:
? Textural values of strobing effect and how it effects output subject dimension accuracy,
? How the subject relates to calibration target accuracy, - set at an accuracy of 0.2mm
? Measured increment diffencing from breath out and breathe in within respiratory cycle.
7.5.2 Tasks carried out to fulfil subject-testing criteria:
? Measuring known subjects that is Tailors Mannequin, 2cm domestic wooden board.
? Simulation testing - simulating breathing on mannequin with padding to added breath
extensions to gain a better understanding of differencing in measurements between
breath in and breath out.
? Realigning calibration of cameras, aperture of cameras and illumination of texturing
projection source to gain maximum accuracy testing.
7.6 Accuracy analysis
Finally a look at the R&D work to assess what has been gained from each experiment and what
information this gives the research as a whole.
8 Experimental testing of Dynamic scanner and out put
information.

All of the following experiments aim to follow aims 3-5 and objectives 2-4 in section 4 they are:
Aims
3. To realize baseline accuracy of the initial output of the Dynamic scanner and compare
with current acceptable accurate margins within the apparel industry at present.

4. To accumulate accurate control data from a standard recognized measuring technique
for example a simple ' tailors tape measure' and produce comparably accurate

results
using the dynamic scanner and additional measuring software.
5. To use basic body landmarks, provided by Doctors, to gain accurate breathing measurement readings from real body captured three-dimensional forms.

Objectives
2.All measurements gained in the study will be accuracy tested against current accuracy
standards within the commercial fashion industry.
3.To design and practice research and development testing mainly on tailors' mannequin
as a form of controlled data, gain comparable data from 'real-life' measuring using
traditional hand measured techniques using a tailors tape and understanding the accuracy of this form of measurement versus digital output data accuracy. Recognize the
accuracy of the output and record all data.
4.Measure a real life subject in a controlled environment using medical breathing
landmarks to gain real life measured data. Then make comparable comments on the control data, whilst finally making comparisons to the standard 1 cm accuracy measurement used in the fashion industry.

8.1 Experiment 1 Three-dimensional object
Experiment Information: Working on inanimate object-wooden board
Experiment information:
In order to understand the data output better as well as understanding the texturing accuracy, a
control object of known dimensions and with a purely flat surface was chosen as an object to be
captured. A section of a large wooden manufactured domestic board was marked out using
masking tape and a square set, the dimensions of this section was not greatly important to this
test as the objective was to test the surface of the board once captured and processed into a
three-dimensional object.
The section was chosen and placed within the scanning space, ready to have a 1 sec 25 frame
capture time; this could then be used to read surface texturing and to see how the object is
translated into three - dimensions. For this to happen it was important to gain a conclusive model
of the board as a totally flat plane.

8.1.1 Process
A 'Real Life' measurement (Real life meaning- that an actual object circumference was
measured, in the standard way using a tailors tape measure) at 24X 32(cm)- measured with tape
measure at source of capture. After one sec (25 frame) statutory capture the results were
processed.

*Note:
The measurements were taken from one frozen three- dimensional plane processed from capture data from the
dynamic system.
8.1.2 Accuracy analysis
The measuring software (for this purpose this will be called 'software a' as it has no trading
name) were, 27 X 35(cm) an accuracy of 3cm + (+ = increase of measurement by shown amount)

This was averaged and found to be approx. 3cm increase from the 'real-life' actual measurement
Whilst it was found that the dimensional values were inaccurate upto the level of accuracy set at
1cm (either side of the form which amounts to 2cm accuracy overall), it was realized at this point
that the calibration settings, mainly the light projection, was causing a textured 'bumpy' relief
patterning. This added a higher overall threshold of 3cm differencing each time from real - life
measurements to software (a) output. Concluding results therefore offered a calibration error as
well as a lighting error.
It was therefore decided the way forward was a new re-calibration to be generated before
continuing the research and development stage of the project. A newly discovered error
increasing concept was the marching cube (mentioned earlier in the subtext of working process
dynamic scanner) the finishing tool that gives better visual results but was found to add a
standard 0.1cm to the resultant measurement every time. This additional finish refining tool could
not be excluded from the system as it was a fundamental/integral part of the finishing process of
the models generated on the system, this error was going to have to be calculated as an
unmovable error at this time.

8.2 Experiments 2 and 3
(Cal: 2 = Calibration 2 reformed calibration from Exp. 1)
(Exp. 2&3: title: Comparison between real life measurement, Software (a) and CLAPA
measuring tools.
Exp. Information: Working from Mannequin using tailors tape.
Experiment information:
This exp. was designed to look at how well the current measuring in house package software a)
could measure a subject dimensionally in this case the tailor's mannequin against another
software package CLAPA. (C LA PA - used currently for cleft analysis in the Glasgow dental
teaching hospital) And result in comparable accurate results to that of the 'real life' measuring
technique.
Certain specifications have to be looked at when comparing the two software measuring tools
firstly the tool has to be user-friendly mainly because time would not allow complex usage.
Secondly the tool has be accurate to the level of the fashion industry standards which is 1 cm
either side of the subjects form. Finally the tool has to be able to store the measured data for
analysis at a later date.

Information on C L A P A, Software: The software visualized the open 3D-captured file on an
interface viewer window with an overall appearance that could be said to be similar Microsoft
windows interfaces. Once the subject in this case the Torso had been viewed the user can then
pin point markers around the area which will create a delineated circumference which will light up
once automatically linked, start point to end point. Once this has been done the circumference will
be given in mm accuracy.
*The CLAPA package, also in house, was being developed parallel to the Dynamic

scanner
research program, so it was very much ‘work in’ progress state and the results were to be fed
back to the developer for future development purposes.
Plate 11: shows a typical CLAPA window shot, the large evaluation window was used to measure the torsos. The two
smaller windows show different angles of the torso
Plate 11

Information on Software (a): this tool was designed and completed by a Ph.D. Student working in
the Faraday Lab, thus far it has been the only tool used to measure any captured form. The tool
has recently been updated and would be suitably fit for purpose, however it is complex to use and
store data.

8.2.1 Process

? A capture was taken of the tailor’s mannequin set at a standard 1 sec. 25 frames statutory
session capture.

? Strobe illumination was used just as before and random landmarks were added as a testing
(R&D) element to see that the markings could be seen on the model after final processing
had occurred.

? Points were placed as landmarks on chest, mid rib, and abdomen, circumference measurements only were taken at this point.

8.2.2 Results

Table 2A results of exp. to understand measuring tool software a) versus ’Real’ hand measured,
measurement:

	Real	Measurement	Difference
Waist	68	64.82	-4.68
Mid Rib	67	65.54	-2.18
Chest	77	76.79	-0.27

Table 2B results of exp. to understand CLAPA measuring tool versus ‘Real’ hand measured, measurement

	Real	Measurement	Difference
Waist	68	64.43	-5.25
Mid Rib	67	64.85	-3.21
Chest	77		

76
-1.30

8.2.3 Analysis of Exp2/3:
(Cal: 2 = Calibration 2 reformed calibration from Exp. 1)
Table 2B shows that the 'CLAPA'- software, gave an average of -3.25% decrease from that of the real-life measurement.
Software (a) measurement tool shows a slightly lower 'difference' result in Table 2A than the CLAPA tool in table 2B. Therefore Software (a) could be the measuring tool to be used throughout the research and development sector. However CLAPA was more user friendly than Software (a) added to this deciding point, Glasgow University required an 'end user test ' of the CLAPA software. Therefore as CLAPA was equally not far from the 'Real' measurement, then it was decided that CLAPA should be used throughout the research and development testing sessions.

Further testing went on from here to ensure a better and more accurate output result however, after numerous attempts at re-calibrations of the camera pods, realigning the screen viewer to a minimized torso view, examining the smoother setting however this was later discarded as the results highlighted that this particular tool was adding to the overall resultant measurement and therefore making the inaccuracy difference increase.
Textural differencing and illumination of the mannequin /model was re-addressed to understand the 'bumping' textural effect, research and advice was taken from previous experiments carried out in order to redefine textural bumping effect on frozen models.
Analysis results of this research were that the strobe illumination technique was to be taken out of the system and replaced with slide projection.
The ultimately concluding effect was better texturing reached because of certain benefits of the projector over 'strobe' illumination:
Sharper contrasting patterning and much more illumination- resulting in smoother surface texture and therefore more accurate measured data.

? At this point more sessions were produced and models processed to find that the new texturing had made a difference. Though it was now recognized that we had hit the peak of the baseline measurement accuracy- that was 2cm- 1 cm over required accuracy sought for the processing of this research.
8.3 Experiment. 4
(Cal: 3 = Calibration 3 reformed calibration from Exp. 2&3)
Exp. 4 Entitled: Quarter turn and Random angle results:
Experiment Information
Mannequin, padding added and taken away to simulate breathing out and in.
The next level of understanding the scanner's accuracy came from an exp. designed to highlight imperfections within the calibration, it is important to know if the whole calibration was working well enough to offer a whole three - dimensional model and that all the cameras were associated effectively. Therefore it was necessary to try to offer an angle to the cameras

that might work
against the calibration set, in brief to try to create an a ‘blackspot’. The other question to be
answered was would the angle that the mannequin was placed effect the final three-dimensional
model form and therefore would it effect the accuracy of the results.
8.3.1 Process:
It was decided that by offering the mannequin at regular and then irregular (random) angles then
irregularities of the calibration would show up with irregular data output thus marking a calibration
error and therefore it would highlight areas which required more work and testing.
This quarter turn procedure was executed by:
? Drawing a small circle around the base of the tailor’s mannequin and marking a quarter angle
around the circle created the base markings to work to.
? The mannequin was then rotated 90 degrees each time (one-quarter turn).
? The mannequin was captured at each 90-degree turn using a 1 sec 25 frame capture
session.
? Throughout the whole exp. a mid-weight padded section was subtracted and added to the
chest and stomach area of the mannequin to simulate breathing in and out.

8.3.2 Results

Table 3A: C L A P A measurements (measurements = cm)

Padding

actual
Measured
Difference
Error
0
Without
62
61.11
-0.89
-1.46%

With
66.5
66.54
0.04
0.06%
90
Without
62
61.36
-0.64
-1.04%

With
66.5
65.93
-0.57
-0.86%
180
Without
62

61.36
-0.64
-1.04%

With
66.5
66.66
0.16
0.24%
270
Without
62
61.28
-0.72
-1.17%

With
66.5
65.76
-0.74
-1.13%

Table 3B, random angle data showing all results with padding off, e.g.: no breathing
simulation added.

actual
Measured
Difference
Error
130
Without
62
61.6
-0.4
-0.65%
220
Without
62
61.7
-0.3
-0.49%
260
Without
62
61.3
-0.7
-1.14%
300
Without
62
60.9
-1.1
-1.81%
360
Without
62
61.01
-0.99
-1.62%

8.3.3 Analysis of Experiment 4
Cal: 3

The results of Table 3A show a smaller error result from the measurements taken using CLAPA against 'real'-measurements taken by hand, than in Table 2B shown in Exp.2&3, this smaller difference was concluded to come from a more accurate calibration. This was concluded because the calibration was the only major element that had changed at the initial stages of the experiment, between the two experiments (exp.2&3 and exp.4). This therefore highlights the importance of striving towards the most accurate calibration possible, in other words the most accurate input therefore logically goes towards creating the most accurate output possible. The random angled resultant data was no more inaccurate than the set angles concluding that random almost obscure angles offer no deformation of the final three-dimensional model.

8.4 Experiment 5

(Cal: 4 = Calibration 4 reformed calibration from Exp. 4)

Exp. 5 Entitled: Final calibration used with authors own Torso capture and 10 measurements.

Exp. Information:

Within this experiment the mannequin was put to one side and real human forms, authors own torso, was scanned and then the output data measured. Along with a real torso it was recognized that there were to be a few problems to overcome. Firstly the body has a Matt skin surface, which unlike the mannequins painted shiny, plastic surface, absorbs light. Therefore lighting must be accurately placed around the body so as to gain optimum amounts of light so that the CCD Cameras can read the body's form. If optimum lighting is not used then the three dimensional model out put will be incorrect.

Secondly the body moves, as well as breathing everybody's bodies move; little involuntary movements, which would have to be captured within the scanning session, so as not to record errors within the session. To do this a trigger was used this associated the CCD Cameras with the computer capturing program.

Third problem and the biggest concern were if the files used, which took up large amounts of computer memory, were to be transferred across the network what effect would this have on the network itself, in short would this cause a network shutdown or crash. If the network crashed it would take a whole sessions worth of work with it.

The main aim of this exp. was to establish a conclusion to whether CLAPA could give equally high standards of accuracy, (working on the industry accuracy of 1cm either side of the body - overall 2cm), on a moving real life model against a stationery mannequin, even after taking in all of the above considerations.

8.4.1 Process

After twenty 'real - life' hand measurements were noted taking ten measurements of the subjects/authors chest and ten of the subjects/authors abdomen.

? Subject /author, stood central to all of the CCD cameras, the subject had arms/hands away from the torso placed in a comfortable position, upon the head. Feet apart, standing at an easy relaxed stance. Breathing normally or as relaxed as possible.

? A three second 75 frame capture was taken. Once the data was captured using the camera trigger an associated trigger which is switched onto capture movement within an

‘AVI’ real
time file when movement requires to be recorded, this trigger was not used when capturing
the mannequin as no movement was required to be captured.
? The three dimensional data captured was then stored as a ‘avi’ file (a ‘real time’ movie file)
from this moving/ breathing model frozen torso sculptures could be chosen, (torso frozen
models were chosen by freezing moving, breathing, images on a viewing window) to

represent breath in and out samples. These frozen torsos were then transferred to the
measuring tool CLAPA, where again twenty measurements were to be noted ten from the
chest and ten from the abdomen/stomach.

To understand how and when the measurements for this exp. were taken it is important to note
the following information on breathing cycle patterns:
As the body breathes in the chest expands and allows the lungs to fill with air. This is when the
breath in measurements was taken. The breath out measurements was taken when the subject
breathed out and the chest had returned to its lowest size.
Plate 12 shows the scanned torso sculpture being loaded into a three-dimensional building cube, within the
the colored sections of the torso represent the different views of each camera association.
Plate 12.

8.4.2 Results

Table 4: breathing out measurements using CLAPA

Breath In values CLAPA

	Chest	Stomach
1	82.5	80.9
2	82	80.9
3	82.2	80.4
4	83.3	80.4
5	82.1	79.9
6	81.9	80.8
7	81.7	80.8
8	82.4	80.3
9		

82.5
80.6
10
82.7
81
Average
82.33
80.6
Std Deviation
0.46
0.35

Table 5: Breath out measurements using CLAPA

Breath out values CLAPA

Chest
Stomach
1
81.7
80.4
2
81.1
80.1
3
81.3
80.4
4
81.7
80.5
5
81
80.2
6
81.3
80.4
7
81.1
80.3
8
81.3
80.5
9
80.7
80.2
10
81.5
80.7
Average
81.27
80.37
Std Deviation
0.31
0.18

Table 6: Breath in measurements using tape - hand measured

Breath in values Hand measured

Chest
Stomach
1
86
81
2
83
81.5
3
84.5
81
4
85.5
81
5
85
81
6
85
81
7
85.5
81
8
84.5
81
9
85.5
81
10
84
81
Average
84.85
81.05
Std Deviation
0.88
0.16

Table 7 Breath out measurements using tape- hand measured
Breath out values Hand measured

Chest
Stomach
1
84
79
2
82
79
3
82
80
4
82
80
5
82
80
6
82
80
7

82
80
8
82
80
9
82
80
10
82
80
Average
82.2
79.8
Std Deviation
0.63
0.42

Table 8: comparison of CLAPA values to actual values

measurement
actual
CLAPA
difference
error %
chest in
84.85
82.33
-2.52
-3.06%
chest out
82.2
81.27
-0.93
-1.14%
stomach in
81.05
80.6
-0.45
-0.56%
stomach out
79.8
80.37
0.57
0.71%

8.4.3 Accuracy analysis
The mean value of a set of data gives the average value, but it does not indicate the dispersion of
the set. For this we need to calculate the standard deviation. The standard deviation takes into
account the deviation of every value from the mean. A lower standard deviation indicates a very
tightly grouped set of data, whilst a higher standard deviation indicates wide dispersions of data.
Comparing the measurement of the breathing out values, tables 5,7, a difference can be seen
between the measurements obtained from CLAPA and the measurements obtained by hand
measurement.
General observations of this data set is that the average chest measurement for the CLAPA
software is less than the hand measurement, but for the stomach measurements the CLAPA

software is higher than the hand measurements.

In order to understand how accurate the software is at measuring ‘real life’ moving subjects. The results of table 8 must be compared with the results of table 3a and 3b. Table 8 compares the average measured data with the average CLAPA measured data. Averages have been used to filter out inaccuracies when measuring a moving subject. The results show that the CLAPA software, when measuring a static subject, were within a +/- 2% and the results also show that the CLAPA software when measuring a moving subject were within +/- 3% of actual measurements.

Possible inaccuracies of Table 8 compared to Tables 3a and 3b could be explained by comparing the two subjects measured in both cases. Firstly the mannequin in exp. 4 was a static subject and as such could be easily hand measured. However the subject in exp. 5 was a moving subject and was measured whilst breathing took place, therefore there was more chance of an error of measurement occurring on the hand measured data which would form the reference data. If this was the case, and it would be fair to summarize that it was, then there were inaccuracies within the reference data before the CLAPA measurements were taken.
The second form of error could have been gained from not estimating the correct maximum sample from the moving image file. The entire freezing of the breath samples were captured by estimating the optimum examples using a viewing screen, the measurement landmarks gained from this could be slightly different to the measurement landmarks used in hand measuring.
Therefore offering another error in CLAPA measurements to hand measurements.
Even after all of these considerations have been made, the final comparisons of data show that the results within Table 8 - column =(difference) are still within the accuracy margins set at apparel industry standards of 1cm either side of the body = 2cm. Apart from one result which can be overlooked as operator measurement error.

8.5 Summary of Experiments
Research and testing experiments presented above were designed to fulfill aims 3-5; this included understanding and finding out if initial data output could give accurate measurements, when measured with an additional software measuring package.
Exp.1 - 4 shows how the individual elements needed to offer this information were individually tested. The final test; Exp. 5 shows how all of the tested elements were incorporated into one final test, which would show how accurate the dynamic scanner could be, and if accuracy could be improved and where any improvements could be made.
Exp.1 tested the surface texture, to test the surface patterning of the scanner means that you can also test the light projection. As it was shown in the test, surface texture can be dictated by the illumination used, for example if the illuminated texture projected onto the body is not bright enough or the random patterning is not in focus, then this results in a bumpy relief patterning on the final three dimensional model. This adds to the final measurement preventing a true and

accurate result. The test concluded in reconfiguration of the light projector unit and in a re-calibration of the CCD cameras.
Exp. 2&3, made comparisons between two 'in-house' measuring tools, certain boundaries were set to be able to control the comparisons. The tool had to be user friendly, accurate and be able to store the measurements shown. The conclusion to this test was that the CLAPA tool should be used as it appeared to be the most user friendly package and as the test concluded by using this tool results and conclusions could be fed back to the programmer to better the tool for the future.
Exp. 4 showed a test that would not only highlight 'blackspots' areas on the cameras view that was not calibrated correctly. It also went to prove the importance of the subjects standing position. It was important to discover if the angle of the subject had anything to do with inaccurate output measurement data. Therefore the mannequin was captured standing at certain angled positions and three-dimensional models were built of the mannequin from every angle position captured. This test resulted in proving that random or set angles reveled no noticeable distortions of the final model and therefore no distorted measurements and therefore it did not appear to matter where the subject was positioned, the outcome was the same.
Exp.5 presented a culmination of the tested elements in exp. 1-4, exp.5 used a real human body and calibration set up, which had been adjusted according to what had been learned from previous experimental outcomes. In this final experiment all of the surface texture had been adjusted and reset, the camera aperture had been re-adjusted and the position of the subject had been determined. The twenty measurements taken from the breath in breath out models on average resulted in an accuracy level of around the value of the control accuracy taken from the fashion industry standard -2cm, which had controlled all measurement standards throughout the research and experimental section.

9 Conclusion

Three-dimensional body scanning is, according to the research used in this paper, becoming an increasingly popular customer incited piece of technology. The textile/fashion industries have adopted the system to become more aware of customer size and shape, and therefore be able to cater for a wider consumer base and gain better understanding of fit. In short the body scanning technology could go towards employing MC - Mass Customisation. Simple, efficient tailoring for the masses, is where the textile and fashion industry is being driven. High street retailers will be able to mass large amounts of customer statistics on file; customers will be able to gain their scanned measurements on microchip, to be used whenever they require purchasing clothing.

This document has shown how many of the body scan technologies differ in how they operate and download data; for example laser base systems versus light based systems. However what really matters at this juncture, is that these systems supply the technology, and therefore the final sizing data that will pull the national sizing systems into the 21st Century and

away from the 1962
survey sizing structure.
'Size UK', as stated previously the largest national survey of its kind in the UK since 1962, is
presently collating data of 30,000 men, women and children from the north to the south of the UK.
The financial support offered by the giants of the fashion industry has been given in the hope that
these project results (published within the next three years) will begin the launch of Mass
Customisation in the UK. The questions about the expense, efficiency, use-ability and accuracy of
the Size UK survey and therefore of the scanning technology and its benefits can only be
answered by looking at the final results in a few years time. However from looking at other like
minded surveys e.g. Caesar survey US (2000), the results of which are filtering through the
American industries at the moment, the outcome looks promising. Some of the Caesar Survey
results have already changed sizing charts used by some fashion suppliers in the US e.g.
'fastskin' -Speedo www.speedo.com, therefore creating better consumer feedback, as well as
going one step closer towards mass customisation.

To look back and conclude upon at the exemplary scanner technology presented within this
thesis (Chapters 4/5), 'the Dynamic scanner', reveals answers to the introductory questions on
how the scanner could gain an accurate set of anthropometric data that could be used within
industry; particular the fashion industry.

The question can be answered in two parts. The first part is that it has been proven within chapter
five of this thesis, that to an extent the 'Dynamic' scanner can offer a set of reasonably accurate
measurement data on the example used within this thesis: breath deformations. When looking at
the summary section of chapter 5 it can be seen that the control accuracy measurement of 2 cm,
(taken as the fashion industry' standard) was reached in the final experiment (5). However the
second part of the answer on the accuracy of the Dynamic scanner, would be that these results
were not precise enough to be taken into the public domain.
Within the process of succeeding a reasonable solution on accuracy within the time limit of three
months, a totally undeniable accurate measurement could not be reached without a few grey
areas within the process being reassessed.
Recommendations for areas that need to be studied in more depth would be CLAPA (measuring
tool), Calibration, and lighting. Firstly CLAPA this tool has been created to be used by
professionals; professors, doctor's experts within their field, all of these professionals with
connections to Dynamic scanner and CLAPA have the research time allowance and skills to
operate CLAPA. However if this tool is to be used within the fashion industry where operators
may not have a Ph.D. and therefore do not have the skills and time allowed to use this
technology. Eventually, if this tool is to be used within a retail environment the time values and
user- friendly issues should be reworked.
The software process requires the operator to download the image form in three

dimensions
ready to be measured. Once the form has been measured then the operator has to come out of
the program and then go into the notepad information at the back of the interface screen for the
measurement details. Within a retail environment working with consumers with no time to spare,
operators will have no time for this complex function.

Another area to look at would be calibration, this is the largest element of the whole scanner
process and yet it is the greatest element of weakness and instability throughout the whole
scanner system. Therefore between every experiment there had to be a calibration adjustment or
total reconfiguration, this whole process was lengthy but necessary to gain the most accurate
reproduction of the scanned image possible. The Faraday Lab. is currently reassessing this
particular area for example; the targets used to set the initial calibration are being reassessed.
The reason for this being that any minor imperfection in the target plate, a dent / bowing of the
plate making an error within the calibration could cause errors of the calibration, and errors of the
measurement data.
To use the Dynamic scanner in industry the calibration technique will have to be made simpler
and less time consuming. Lighting would be another concern, but then the Faraday Laboratory is
currently addressing this. Basically the lighting within Dynamics configuration needs to be
updated. Illumination is so important to the scanners functionality, that the Michael Angelo
Foundation – (the board of people assessing and researching into the Dynamic scanner) have set
aside funding to post an illumination engineer to the Lab. to assist with gaining maximum
illumination within the scanner studio area. As well as more efficient 'black out' techniques and
better lighting are being researched and sourced.
In light of the conclusions above that the Dynamic scanner is not yet ready to be proposed to the
fashion industry, thoughts on future end use values of the dynamic scanner can only be
hypothesised and speculated upon.
An innovative, educated guess, of 'end use' of this technology would be a virtual tailor's model. A
captured image of a real human body would be stored on disk ready to visualise designers
fashion creations. Patterned rendering techniques, currently used on three-dimensional animated
models could be paired with the Dynamic animated files, to reveal a three – dimensional, virtual
breathing mannequin that could be used to market and realise ideas and images from designers
CAD drawings.
The benefits of this kind of technology would be unbounded, demonstrations would be more
realistic, once three –dimensional mannequin were filed and stored on hard drive this data could
be translated to the internet and used on – line. Possibly in the virtual dressing rooms that are
appearing online more and more.
Internet based companies are offering virtual 'dressing room' sites e.g. www.chicjeans.com,
www.MyVirtualModel.com and updates of the virtual dressing rooms are featured on

www.news.cornell.edu.

These sites offer the user an insight into how their body shape would look in a virtual item of
clothing, therefore assisting users to purchase shape and fit to suit their own shape and size.
Draping software is currently being researched and designed to cater for virtual drape that will
imitate how a garment is held on the body. This is another step towards virtual dressing rooms,
and realistic styling on-line.
Istook and Hwang (2000) have echoed this thought,
"Study should be undertaken on how this technology might support virtual dressing or garment
try-ons, as well as on the technical approach used in software development, testing and
evaluation."
In short there is no definitive conclusion to the outcome of the Dynamic scanner or how the other
scanner technologies will fair in the future. This whole area is continually rolling and updating, the
fashion market has been found to want to research and fund the various scanner projects, but as
with anything innovative and new there are grey areas for concern and redevelopment. Therefore
the final statement, however profound it may be, has to be 'watch this space…'
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