AN INSIGHT INTO THE DESIGN, MANUFACTURE AND PRACTICAL USE OF A 3D BODY SCANNING SYSTEM

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An insight into the design, manufacture and practical use of a 3D scanning system

This presentation will consist of two sections; an explanation of the design of a 3D body scanning system, followed by a description of applications that make use of such technology.

An insight into the design of a 3D body scanning system will be presented, from the initial concept through to manufacture. Various design considerations, including the available scanning technologies, will be discussed. The resulting commercially available body scanning system hardware and software will then be described in more detail.

The second part of the presentation will focus on applications possible today using such technology. Finally, suggestions for future directions of 3D body capture will be discussed.

The Design of a 3D Body Scanning Booth

An Introduction to Wicks and Wilson

Wicks and Wilson was formed in 1973 to manufacture and supply microfilm aperture cards and chemicals to the rapidly growing micrographic industry.

With the advent of the first desktop computers in the early 1980s, the company started to design and manufacture electronic imaging equipment for the micrographic industry. The products included scanners and plotters that used the latest imaging technology.

In 1996 Wicks and Wilson were approached by a London teaching hospital that needed a commercial partner as part of a 3D facial scanning project. The core activity of Wicks and Wilson was electronic imaging and it was seen as an ideal opportunity to enter an alternative marketplace.

This project led to the development of TriForm, a method of 3D scanning using a variation of the moiré fringe technique. TriForm systems have since been developed for a number of applications including head scanning and full body scanning.

Today the company employs 65 people at its Basingstoke headquarters in the UK and are now recognised as market leaders in the micrographic world, with a complete range of microfilm scanners. There is also a dedicated team working on the design and promotion of the TriForm range of products with the aim of making it the best human capture system available on the market.

TriForm technology

When the project was started, the most appropriate method of capturing a 3D surface had to be chosen. The initial purpose of the TriForm project was to design a system for 3D facial imaging. The system therefore required a technology that could accurately and reliably capture three dimensional colour scans whilst being totally safe and acceptable to the person being scanned.

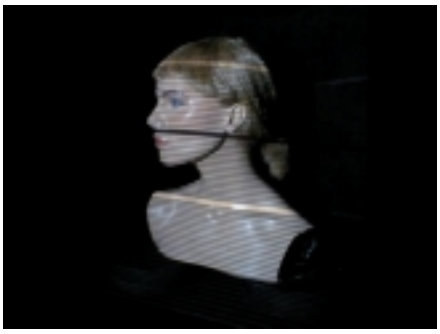
There are several different methods of 3D scanning, but it was decided that structured light provided the best overall solution for the facial scanning application.

Attributes of different scanning techniques

	Structured Light	Infra-Red	Laser Progressive	Stereo Matching	Focal Plane	Radar
Capture speed	✓	✓	✓✓	✓✓	✓	✗
Colour	✓	✗	✗	✓	?	✗
Accuracy	✓	✓	✓	?	✓✓	✗
Range	✓	✓	✓	✓✓	✗✗	✓
Safety/ acceptability	✓	?	✗	✓	✓	✗
Processing speed	✓	✓	✓	✗	✗✗	✗

Principals of structured light technique

A series of fringes (parallel horizontal black and white stripes) are projected onto the scanning subject). Each fringe pattern is captured by a camera and frame grabber board then stored in the PC controller. An additional 'all white' frame is also captured and used to produce the colour texture map of the subject.



The fringe patterns are processed by analysing the distortion in the lines as they fall onto the curved surface of the subject. Points with x, y and z co-ordinates and colour information are calculated to produce a full colour 3D point cloud.

First TriForm Design

The original design of TriForm used a single projector/camera pair to capture the 3D geometry and colour of a surface. The unit was simply mounted on a tripod and had the ability to capture approximately 120 degrees of data.

The system process and concept was extensively tested and proven using this configuration.

Move into Body Scanning

A major shift in the focus of TriForm development efforts occurred nearly two years ago when Wicks and Wilson attended a mass customisation conference in April 1998. The possibilities of applying the TriForm 3D capture technique in the garment industry were discussed and trials using two tripod mounted scanners to capture body shape were carried out a few months later.

The results were presented to a number of clothing retailers and the response was so encouraging that a decision was made in mid-October to design a full body scanning booth. This led to the delivery of the first ever booth just 16 weeks later, demonstrating the advantage of having all mechanical, electrical and software design teams all under one roof as we do at Wicks and Wilson.

Designing a body booth

From the outset, the principle market for a 3D body scanning system was identified as the garment industry. The potential for a booth that gained acceptance in this market was huge, but several important factors were introduced that had to be taken into consideration when designing and building the TriForm BodyScanner booth.

Size
Retail space is expensive and forms a significant part of the overhead for any retail business. For this reason, the footprint occupied by the BodyScanner booth had to be as small as possible.

Using the original layout of four tripod mounted cameras would have resulted in a booth measuring 3.5m x 3m. However by developing a patented folded beam approach using mirrors, it was possible to produce a scanning booth with a footprint of just 2.5 x 1.5m.

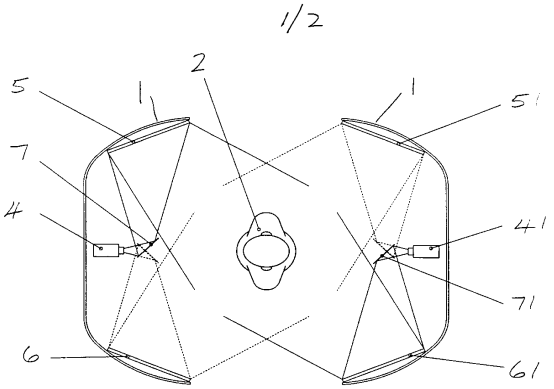


fig. 1

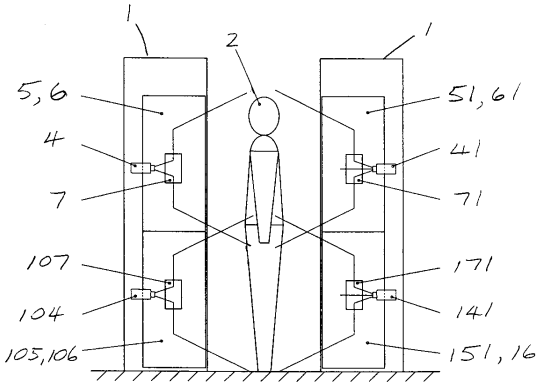


fig. 2

Cost
An added benefit of such a method was a significant reduction in hardware cost. To capture the entire surface of the human body in one scan sequence requires a total of eight cameras. Four cameras are required to capture the front view of a subject; top left and right, bottom left and right. The same number of views are also needed to capture the back, giving a total of eight camera/projector pairs.

By using the folded optics, a complete 360 degree surface can be scanned using just four camera/projector pairs without having to rotate or move the subject.

Modular construction
Initially this was an internal requirement so that the booth could be easily assembled and broken down to allow for transportation with minimal hassle. However one of the areas where 3D body scanning technology is being applied in the garment industry today is in the collection of body sizing data. The surveys often take place at a number of locations to get a broader sample of the population. An easy to assemble modular construction

allows the TriForm BodyScanner booth to be moved from town to town or even from country to country without the need for complete recalibration every time it is built.

Returning to the cost factor, the other advantage that modular assembly offers is to simplify the manufacturing process. Wicks and Wilson have a fully ISO approved manufacturing facility which is capable of producing the TriForm BodyScanner booth in substantial quantities.

Customer Acceptance

If body scanning technology is to succeed in a retail environment, the customers have to readily accept it. For this reason, the technology developed for TriForm uses normal white light as described earlier. There are no perceived safety concerns with this type of technology and, if the scanning is presented and marketed in the correct way, the scanning experience can actually be enjoyable.

For accurate measurements to be taken from a scan, the subject must be scanned whilst wearing underwear, or second-skin clothing. The booth has therefore been designed to have the appearance of a normal changing booth found in shops today, an environment that suggests privacy where people are already used to removing their clothing.

Hardware components

As described earlier, a structured light technique is used to capture the surface of the subject. This technique requires a projector to project the fringe patterns onto the subject and a camera and frame grabber board to capture that image. It takes just a few seconds to complete a scan sequence that captures all views required to produce a complete 360 degree body scan. This method, combined with the folded mirrors, results in an uncomplicated hardware design that is both affordable and reliable.

Software components

A significantly high proportion of the TriForm project is software based. Once the raw data images have been captured from the scan sequence, all other processes are carried out on a PC. Faster and faster PCs today allow for image processing that before was limited to high end workstations.

The TriForm BodyScanner system has been designed to capture body shape in three dimensions and reproduce it accurately, together with the surface colour, in a PC environment. The TriBody software package has been produced by Wicks and Wilson exclusively for the TriForm system. TriBody provides all of the functions required for

the capture, processing, and alignment of a 3D body surface. The usual viewing facilities, such as the ability to rotate, zoom and translate the image are included as well as a number of analysis tools for manual measurement.

Once the image has been produced by the TriForm capture, it can then be integrated with other 3D software packages (e.g. automatic measurement extraction, animation) by storing images in an appropriate 3D file format.

Practical use of a Body Scanner

Scanning Procedure

The TriForm 3D capture system has been designed to be as simple to use as possible. An operator does not need to have any specific 3D experience.

Pressing SCAN in the TriBody software initiates the scan sequence. Once this is complete, the raw data is processed to produce a 3D point cloud with x, y & z co-ordinates and associated colour data for each point. When all eight clouds have been processed they are automatically aligned relative to each other, first by dead reckoning then by cloud matching.

Once the clouds have been aligned, they can be merged into a single point cloud if required before being saved.

Example Scans

The Wicks and Wilson web-site contains some sample images produced using the HeadScan and BodyScanner systems. Please visit us at;

http://www.wwl.co.uk

Practical scanning

As already discussed, 3D scanning must be accepted by the public if it is going to be used seriously in the garment industry. Gaining this acceptance probably has more to do with the way the scanning experience is presented and marketed, rather than the actual scanning process itself. However, the complete scan process from entering the booth to producing the scan must be completed in an acceptable amount of time. The customer will not want to be kept waiting around for too long, and the retailer will want to have maximum throughput to help keep costs down.

Movement

One potential problem with scanning people is sway, or movement during the scan. It takes a finite amount of time to complete a scan sequence and it is possible that the scanning subject could move during this time. If the subject does move appreciably, then the data cannot be processed to produce an accurate surface.

To reduce the problem of sway, handles have been built into the booth so that the subject can hold onto them during the scan and steady themselves. Also, a quality monitor automatically detects if the subject has moved and immediately signals that a rescan is required. This minimises the impact that any rescan has on the total scan time.

Further improvements to the system are expected to reduce the issue of sway to minimal levels.

Posture and Pose

Posture is a very important consideration when scanning people. You often only have one opportunity to capture a person – so what pose should they adopt throughout the scan? The most important information to have when deciding on posture is knowing what the scans are for and how they are to be used in the future.

For example, a typical application is for body sizing surveys. This application requires all surfaces to be captured so that reliable measurement information can be extracted from them. A traditional pose with hands by the side of the body is not appropriate because this prevents waist and chest measurements from being taken. Instead the handles can be used to draw the arms away from the body, thus allowing most measurements to be extracted.

Some applications may require multiple scans, for example a sitting pose may be required for certain measurements. When choosing a pose, think about what you need to get from the scan and then make sure that the pose you choose allows that surface to be seen by both the projector and camera. If this is the case, then it will be captured successfully.

Applications

I have already mentioned that the garment industry probably has the greatest potential for using body scanners. To illustrate this, I will now discuss a number of applications within the garment industry.

Body sizing surveys
Body sizing surveys are being carried out in countries around the world and 3D scanners are being used for the first time in addition to the traditional tape measure method. There are many advantages to using a 3D scanner and later presentations will cover this in more detail. Suffice to say that if used effectively, body scanning not only reduces time and labour costs, but also has the advantage of capturing shape as opposed to just measurements in a tabular form. This shape information can then be used to produce standard sizes that are more appropriate to people today.

Custom fit
A body scanner can be used to capture the shape of a customer and measurement extraction software can be used to extract measurements from it. These measurements can then be stored on an appropriate media (e.g. smart card, web-site etc) and used to manufacture custom clothing to fit that particular customer.

Companies that have a corporate uniform can also benefit from the use of a body scanner to produce better fitting clothing for their employees without having to take many manual measurements. This is known as collective measurement and is currently being used by a number of armed services around the world to give their recruits better fitting uniforms.

An extension of this application is mass customisation, the holy grail of the clothing industry. If a store could offer custom made clothing to all customers from all branches it would be a significant advantage over their competition. Today there are a number of barriers which prevent stores from providing this ultimate service, principally the logistics of scanning, manufacturing and delivering the garments in an acceptable time frame.

As an interim step, a best fit service can be offered where a customer's measurements are used to guide them straight to the size and style of clothing that offers the best fit off the shelf.

Internet shopping
Body scanning can be used to enhance internet shopping sites in a number of ways. First of all from a visualisation point of view, it would be preferable for a customer to see themselves dressed in the clothing to see what they look like from all angles before making a purchasing decision. This application exists today in the form of avitars, but it won't be long before you can actually dress yourself instead of a virtual mannequin.

Additionally, by having the body scan of a customer the Internet retailer knows their exact measurements so that clothing can be supplied in the correct size first time. Today mail order companies have approximately 40% of their stock returned for various reasons, but mainly because the fit isn't right. Anything that can be done to reduce that figure saves cost immediately.

Animation
The final market that offers a huge potential is the animation market. That could be animation in movies or animation in computer games. This is such a fast moving industry that software houses are always striving to find ways to make their games more and more realistic. Guiding yourself down a ski slope or through a war zone is probably about as realistic as it can get without actually doing it!