ETUDE DU CYCLE DE RESPIRATION A PARTIR DE DONNEES 4D GENEREES PAR UN SCANNER DYNAMIQUE 3D

STUDY OF THE BREATHING PATTERN BASED ON 4D DATA COLLECTED BY A DYNAMIC 3D BODY SCANNER

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Résumé

Le laboratoire de recherche 3D-MATIC de l'université de Glasgow développe un scanner dynamique 3D pour le corps entier. Le concept de base est d'équiper un studio afin que le "volume de travail" dans cet espace soit photographié de toutes les directions par des paires stéréo de cameras de télévision. Les paires d'images stéréo photographiées à une fréquence de 25 Hz sont alors traitées en utilisant des techniques photogrammétriques afin de créer un model 3D spacio-temporel de cet espace.
En utilisant ces uniques données 4D, il est alors possible d'étudier les déformations de formes 3D. Nous présentons quelques résultats préliminaires sur l'étude du cycle de respiration de quelques individus. Cette recherche s'intéresse à l'acuité des données générées et en particulier à leur adéquation vis à vis des standards de l'industrie textile. Finalement, nous nous intéressons aux applications potentiels de scanners dynamiques 3D dans l'industrie du vêtement.

Study of the breathing pattern based on 4D data collected by a dynamic 3D body scanner

Abstract

The 3D-MATIC Research Laboratory at the University of Glasgow is currently developing a dynamic 3D whole body scanner. The basic concept is to equip a studio space such that the "working volume" of the space is imaged from all directions using fixed stereo-pairs of TV cameras. The stereo-pair images, collected by the camera pairs at a frame rate of 25 Hz, are then processed using photogrammetric techniques to create a spatio-temporal 3D model of this space.
Using these unique 4D data, it is now possible to study 3D shape deformations. We present some preliminary results of a study of the breathing pattern of a couple of subjects. This research investigates the accuracy of the data and how it compares with the measurement standards of the fashion industry. Finally we discuss the potential use of dynamic 3D scanners in the apparel industry.

Study of the breathing pattern based on 4D data collected by a dynamic 3D body scanner

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1. Introduction

The 3D-MATIC Research Laboratory at the University of Glasgow is currently developing a dynamic 3D whole body scanner: a 3D scanner that has the ability of performing 25 scans per second. Data collected by this scanner can be used for many types of applications that can be divided in 2 classes: the generation of true 3D films [Ne01b] and the study of 3D shape deformations. In this paper, we focus on the later one. More precisely we will study the breathing pattern of individuals in a view of using our system in the apparel industry.

We start by describing our dynamic 3D body scanner, then we evaluate its accuracy compared to the textile industry standards and finally we present some preliminary results of a study of the breathing pattern of a couple of subjects.

2. Dynamic 3D body scanner

2.1 Principle

A dynamic 3D whole body scanner is a piece of technology that has the capability of capturing 3D data using scanning techniques at a frame rate of 25 scans per second. Since the capture time of the scanner has to be very fast, we use a scanner based on photogrammetry which has a capture time of few milliseconds [Si00]. Therefore that gives us the ability to capture subjects at a frame rate of 25 scans per second. The prototype of the 3D studio we are currently developing allows the 3D capture of a scene fitting a 2 metres side cube, typically we can capture the motion of a single person. The scene is imaged by a total of 24 TV cameras arranged in threes -we term a group of three cameras a pod (see Fig. 1).

Figure 1: A pod

The configuration of this scanner is the following: eight pods are arranged at the corners of a parallelepiped to image the active volume (see Fig. 2).

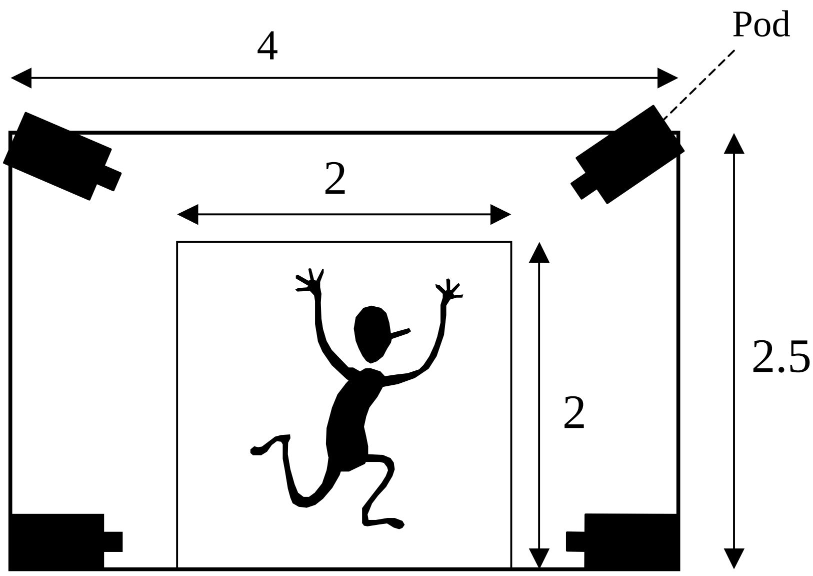

Figure 2: Configuration of the scanner (distances in metres)

2.2 Dynamic 3D data capture

The process of 3D capture relies upon flash stereo photogrammetry. Each pod has one colour and two black and white cameras. Associated with each pod are two strobe lamps, one of which is a flood strobe, the other is fitted within a modified overhead projector which illuminates the scene with a random dot pattern. At the rate of 25Hz successively, the colour cameras capture the scene illuminated with uniform white light, and then the mono cameras capture the scene illuminated with the texture. The total capture time is under 450 µs. The monochrome images are used for stereo range finding and the colour images are used to capture the surface appearance of the subject.

In order to build 3D models from the data captured by the scanner previously described, the cameras have to be calibrated, e.g. the detailed geometric configuration of all the cameras has to be known. Then once the capture has been done, the stereo matching process is applied to each stereo-pair images. The algorithm we use is based on multi-resolution image correlation [Zh88].

Once the stereo matching process is completed, the final displacement files combined with the calibration file of the associated pod allow the generation of a range map, i.e. the map of the distances between each pixel and the coordinate system of the pod. Since the pods have been calibrated together, the 8 range maps of a given time step can be integrated in a single coordinate frame. An implicit surface is computed that merges together the point clouds into a single triangulated polygon mesh using a variant of the marching cubes algorithm [Lo87]. This mesh is then further decimated to any arbitrary lower resolution for display purposes.

The generation of photo-realistic models is achieved by mapping the colour pictures taken by the colour cameras to the 3D geometry. On Fig. 3, a sequence of photo-realistic 3D models, generated from four pods, is presented.

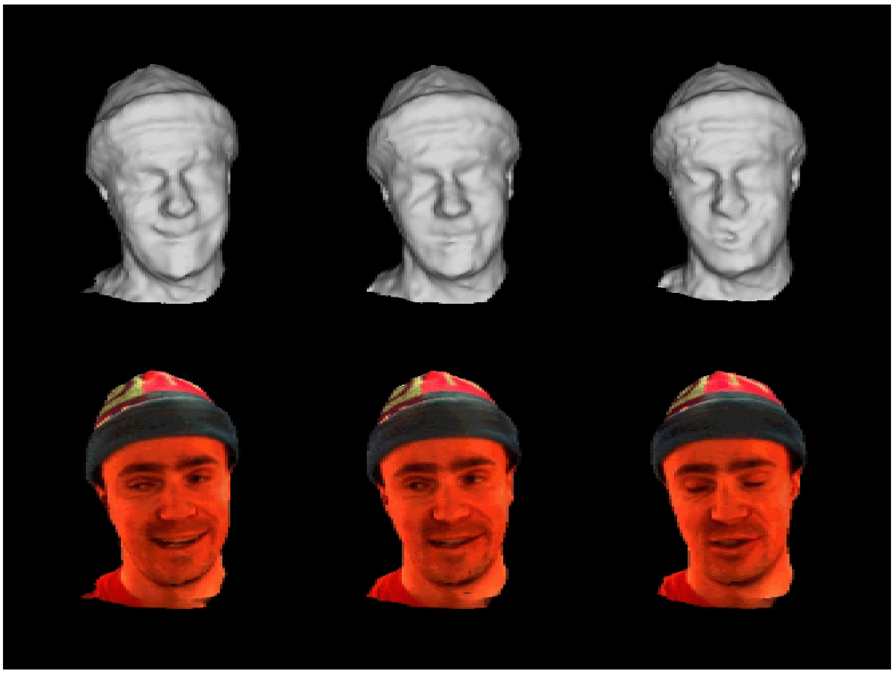

Figure 3: Sequence of photo-realistic 3D models

A more detailed presentation of our dynamic 3D capture system is given in [Ne01a].

3. Study of the breathing pattern for the textile industry

3.1 Motivation

Lead by medical and military researches, three-dimensional body scanners has begun to become a mature technology. 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 in 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.

At the other end of the spectrum, shops are getting equipped of 3D scanners to offer customised garments to specific individuals claiming a 100% fit. Unfortunately garments close to the body like lady lingerie, extreme weather clothing and sports wear can still become uncomfortable after long periods of wear: a 100% fit based on static 3D data cannot be achieved for a dynamic body. Instead, pattern design and cutting should be based on dynamic 3D data. For example, the dynamic scan of a breathing torso would show life-like fabric distortions on the chest and abdomen. That could be used to gain more accurate modelling effects and therefore a more accurate fit. The designer could test friction of specialist garments used for closer fit whilst the subject is in motion. Garment design for military usage could also benefit from dynamic models; the effect of wear on fabric and life expectancy of expensive uniforms could be evaluated more easily.

3.2 Experiments

In order to investigate the potential of our system for the apparel industry we study the breathing pattern of individuals.

3.2.1 Anthropomorphic and respiratory land marking

To gain a set of measured data from a human breathing cycle, we need to land mark areas that give maximum differentiation between the inflation and deflation of the torso whilst in the process of breathing at an average rate of 15 cycles per minute. We decided to study two circumferences of the human torso in order to cover the two main types of breathing (either with the chest or the stomach), which generally are linked to the gender of the individual. For women, the best place of reference is the chest -3rd mid rib- where the skeletal structured points on the body should protrude the farthest within the breathing cycle. For men, the abdomen/stomach area - directly across the navel- should show the greatest muscle deformation area within the breathing cycle.

3.2.2 Scanner accuracy

The accuracy of data generated by a 3D scanner is one of the key information needed to access if a scanner is suitable for a specific application. Unfortunately this value is difficult to assess and comparisons between scanners is virtually impossible since there is still no protocol established for evaluating the accuracy of a 3D scanner [Ma01]. However it seems reasonable to assess the accuracy of a scanner for a very specific task such as measuring circumferences on a breathing human trunk. Moreover this accuracy needs to be compared with the standards of the industry that is our target: the textile/ fashion industry standard for cutting is of 1 cm, which means that a given piece of cut fabric has its dimensions known in a range of 2 cm. This is the standard our scanner needs to comply with.

In order to generate dynamic models of torsos, we set our scanner in a 4 pod configuration. The accuracy of the data it generates was assessed by scanning a static mannequin in around one hundred of positions inside the volume of interest. We thought that moving the mannequin inside the scanning volume specially in changing its orientation was very important to ensure that the measured accuracy was not position dependant. Padding were also added and taken away from the mannequin to simulate breathing out and in.

Practically the mannequin was positioned at regular and then irregular angles from a pod of reference to detect potential errors generated during the calibration and the merging of the data generated by the 4 pods. Throughout the whole experiment a mid-weight padded section was subtracted and added to the chest and stomach area of the mannequin to simulate breathing in and out. The measurements taken on the 3D scanned were made manually using a homemade tool.

Angle (deg)	0	90	180	270	Average	Max
Without padding						
Actual (cm)	62	62	62	62	62	62
Measured (cm)	61.11	61.36	61.36	61.28	61.2775	61.11
Difference (cm)	-0.89	-0.64	-0.64	-0.72	0.7225	-0.89
Error	0.0146	0.0104	0.0104	0.0117	0.0116	0.0146
With padding						
Actual (cm)	66.5	66.5	66.5	66.5	66.5	66.5
Measured (cm)	66.54	65.93	66.66	65.76	66.2225	65.76
Difference (cm)	0.04	-0.57	0.16	-0.74	0.2775	-0.74
Error	0.0006	0.0086	0.0024	0.0113	0.0042	0.0113

Table 1: Measured values to evaluate the accuracy of the scanner

The results of Table 1 show an error of 0.27 cm in average from the measurements taken on the scans against ‘real’ measurements taken by hand with a measure tape. Moreover there is no correlation between the angle and the error. The average error and the maximum error (0.74 cm) being well above the standards of the fashion industry (2 cm), that means the scanner is suitable for our study.

3.3 Study of the breathing pattern

Since we were dealing with a preliminary study with limited resources we decided to scan only 2 individuals a female and a male. They were ask to breath as normally as possible and were scanned for 3 seconds. Then two extreme positions of their breathing cycles were analysed by measuring the circumferences at the chest and stomach levels, where landmarks were drawn before the capture (see Fig. 4).

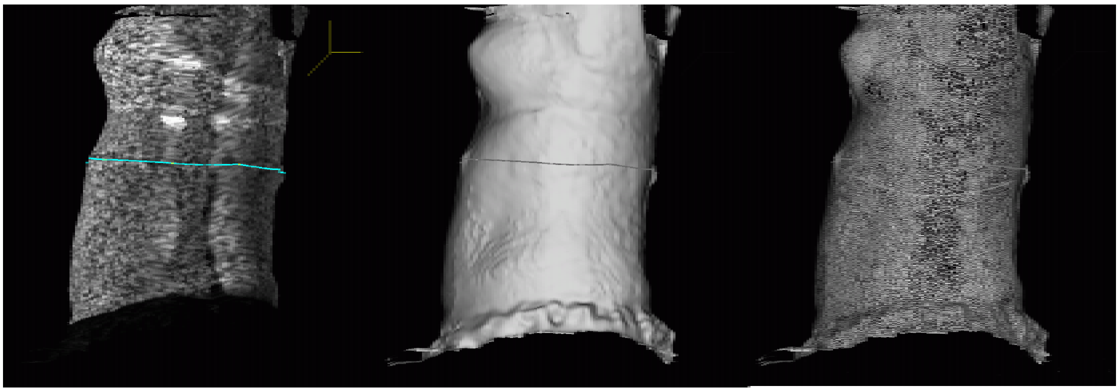

Figure 4: 3D model of a torso being measured

	Breath Out	Breath In	Difference
Chest (cm)	82.33	81.27	1.06
Stomach (cm)	80.6	80.37	0.23

Table 2: Measures on a slim female

	Breath Out	Breath In	Difference
Chest (cm)	89.15	89.35	-0.20
Stomach (cm)	90.65	89.98	0.67

Table 3: Measures on a slim male

Since the average inaccuracy of the scanner is around 0.3 cm, the circumference differences of the stomach in the female case and the chest in the male case are not meaningful (see Tab. 2 and Tab. 3). However the two other values are above the scanner accuracy and demonstrate what was expected before starting this preliminary study: women breath with their chest and men with their stomach.

These first results are encouraging; our dynamic scanner seems to be able to measure circumference variations within the breathing cycle. Obviously this pre-study should be followed by a more complete study where a wider range of people would be scanned. Such a study should be sponsored by a garment manufacturer that would specify which circumferences and landmarks should be tracked during specific motions. These measurements could be extracted automatically from sequences of 3D models using the tools already developed for size surveys based on 3D scans [Tr00].

4. Conclusion

We presented in this paper a new type of 3D scanners: a dynamic 3D scanner that has the capability of performing 25 scans per seconds. Since 3D scanners have already been adopted by the textile/fashion industries either for conducting size surveys, tailoring garments to specific individuals or offering online catalogues, we believe dynamic 3D scanners would be a useful complement in the process of designing garments aimed at “dynamic” bodies.

A pre-study showed our dynamic scanner can claim - in the specific context of circumference measurements of a human torso - an accuracy that is better than the control accuracy measurement of 2 cm (taken as the fashion industry’s standard). Moreover we successfully managed to measure circumference differences between the inflation and deflation positions for a couple of subjects (male and female). These values were consistent with what was expected: women breath with their chest and men with their stomach.

We expect to start a more complete study in the near future in collaboration with a garment manufacturer. They would help us to focus our research on the measurement of specific landmarks relevant to particular garments.

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