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Digitization of the human body in the present-day economy

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ABSTRACT

In this paper we report on the historic development of human body digitization and on the actual state of commercially available technology.
Complete systems for the digitization of the human body exist since more than ten years. One of the main users of this technology was the entertainment industry. Every new movie excited with attractive visual effects, but only few people knew that the most thrilling cuts were realized by using virtual persons. The faces and bodies of actors were digitized and the "virtual twin" replaced the actor in the movie. Nowadays, the state of the human body digitization is so high that it is not possible any more to distinguish the real actor from the virtual one. Indeed, for the rush technical development has to be thanked the movie industry, which was one of the strong economic motors for this technology.
Today, with the possibility of a massive cost reduction given by new technologies, methods for digitization of the human body are used also in other fields of application, such as ergonomics, medical applications, computer games, biometry and anthropometrics. With the time, this technology becomes interesting also for sport, fitness, fashion and beauty. A large expansion of human body digitization is expected in the near future.
To date, different technologies are used commercially for the measurement of the human body. They can be divided into three distinguished groups: laser-scanning, projection of light patterns, combination modeling and image processing. The different solutions have strengths and weaknesses that profile their suitability for specific applications. This paper gives an overview of their differences and characteristics and expresses clues for the selection of the adequate method. Practical examples of commercial exploitation of human body digitization are also presented and new interesting perspectives are introduced.

Key words: human body, measurement, laser scanning, light projection, modeling, fashion

1. INTRODUCTION

Complete systems for the digitization of the human body exist since more than ten years. One of the main users of this technology was the movie industry. Its visual effects had to appear more and more realistic and this was not possible any more by using computer graphics only. A new idea stuck: replace the real actors with virtual ones. A representative example is the movie "Teminator 2", which was turned in 1991, already thirteen years ago. At that time, the cost of a full body scanner was still over 400,000 US$. The military industry had also these equipments, but its application was primarily ergonomics: seats of combat airplanes could, for example, be fitted exactly to pilots.
New methods and techniques were continuously developed for the digitization of the human body and new tools were introduced for a more efficient use of the resulting data. The number of available solutions increased. With the possibility of a massive cost reduction given by the new technologies, human body digitization became interesting also to other fields of application. With the time, the different solutions profiled themselves more clearly with their strengths and weaknesses. Therefore, it is important to know deeply their characteristics and differences, for the selection of the adequate solution for a specified application.

2. ACTUAL STATE OF TECHNOLOGY

Technologies used commercially for the measurement of the human body can be divided into three different groups:

- Laser scanning,
- Projection of light patterns,
- Combination modeling and image processing.

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2.1. Laser scanning

Laser scanning technology consists of using lasers to project on the human body one or more thin and sharp stripes (Fig. 1 left). Simultaneously, light sensors acquire the scene and by applying simple geometrical rules (named "triangulation", Fig. 1 right) the surface of the human body is measured. To assure the inoffensiveness of the light beam, only eye-safe lasers are used. Special optical systems and mirrors are used for the generation of stripes from a single laser light beam.

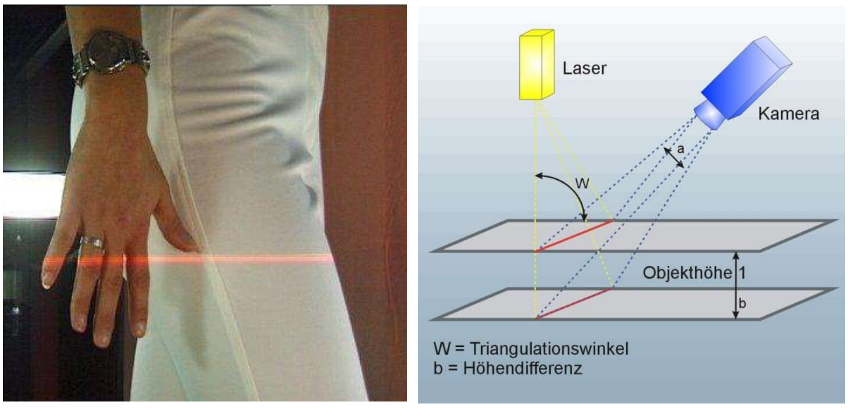

Fig. 1. Left: laser stripe on the human body. Right: triangulation method, different object heights result in different triangulation angles that can be measured by the light sensor (images of Vitronic).

A laser scanner unit is composed of the laser, the optical system and the light sensor. This unit is moved across the human body to digitize the surface. The type of movement and the number of employed units can vary depending on the human body parts to be measured. For example, the full body scanner of Hamamatsu Photonics (Fig. 2 left) consists of four scanner units that move vertically synchronously along four pillars. A second example is the head scanner of Cyberware (Fig. 2 center). In this case, a unique scanner unit moves in circle around the head of a person. As last example is shown the foot scanner of Vitronic (previously Tecmath): the scanner is composed of three units, which moves horizontally, two laterally and one from the bottom (Fig. 2 right).

Fig. 2. Laser scanning systems. Left: full body scanner *BodyLine* of Hamamatsu. Center: head scanner *Head & Face 3030 3D Color Scanner* of Cyberware. Right: foot scanner *Pedus* of Vitronic.

The high costs for production of hardware components for the laser scanning technology have to be considered as disadvantage. Additionally to the laser, the light sensor and the optical system, also precise electric motors have to be used for the displacement of the scanner units. Moreover, the complete scanner system has to be calibrated so that the geometrical disposition of all the elements can be determined exactly. A second disadvantage of this method is the time required for the digitization of large surfaces. There is no problem for the measurement of extremities as feet and hands, since these body parts can be kept immobile for some seconds. But, in the case of the measurements of head or full body, it is practical impossible to stay immobile for several seconds. Uncontrolled movements as breathing or muscle contraction can generate errors, especially in the case of face measurement with its small scale and its required large resolution.

2.2. Projection of light patterns

The second technology is based on the projection of light patterns. It comes closer to the solution of the problems described above. Instead of moving the scanner unit, a light pattern (usually in form of stripes) is projected onto the human body (Fig. 3 left). A light sensor (e.g. a digital camera) acquires the scene. The scanning device is composed usually of a pattern projector and a light sensor (Fig. 3 center). More complex systems use two or three light sensors. The measurement process is similar to the method of laser scanning: stripes on the surface are measured singularly by using triangulation. The difference is that this happens in a single step and that the entire surface can be digitized by a single acquisition. For the increment of the resolution, the projected stripes are shifted and multiple scenes are acquired. Everything happens in short time period (mostly under one second), so that human bodies can be digitized without problems: the uncontrolled movements of the person are not a problem. However, the field of measurement of such scanning devices is limited, e.g. *Capturor* of InSpeck (Fig. 3 center) can measure surfaces with maximal size of half part of the human body (e.g. upper torso). To measure large parts of the human body (e.g. entire head, full body) multiple scanning devices are required. Fig. 3 shows on the right an example of a full body scanning system composed of six scanning units. This procedure has the disadvantage, that multiple units cannot be used simultaneously since they interfere with each other's light patterns projections. Practically, this means, that multiple equipments have to be used serially. This implies again an extension of the acquisition time.

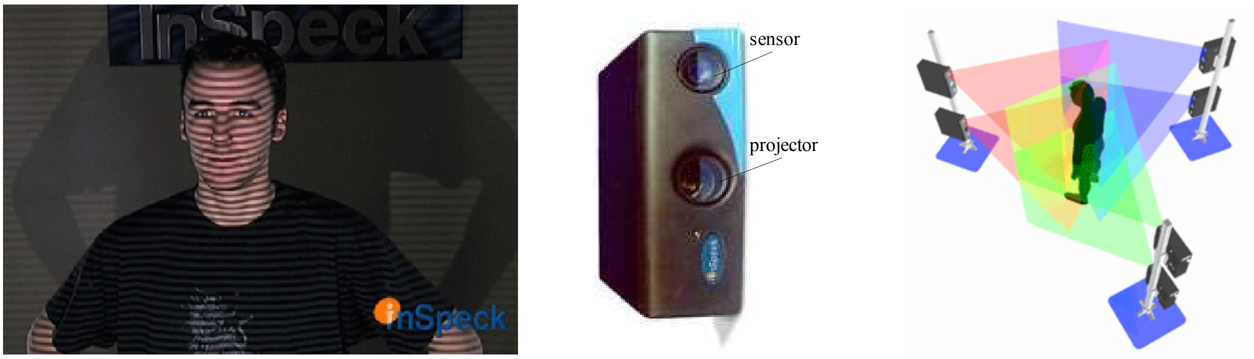

Fig. 3. Left: projection of light pattern as stripes. Center: scanning device *Capturor* of InSpeck. Right: six Capturors compose a full body scanning system. (Images of InSpeck.)

More advantageous, in comparison to laser scanning, are instead the today's costs of the technology. A very simple solution is for example shown in Fig. 4 left: a usual digital camera and a light projector. The special holding serves for a simplified calibration process (determination of the geometrical disposition of all the elements). In Fig. 4 right, is displayed, as second example, the full body scanner *TriForm* of Wicks and Wilson; to note are the holdings for the hands for a simplified immobilization of the person during the measurement process.

Fig. 4. Left: scanning systems with projection of light: *Shapesnatcher* of Eyetronics (camera and projector). Right: full body scanner *TriForm* of Wicks and Wilson.

2.3. Image processing and modeling

The third technology utilizes image processing and modeling techniques for the digitization of the human body. In this case, 3D measurements are not performed, but 3D information is generated and extracted from 2D. Two examples are described to explain this technique: the 2D full body scanner *Contour* of Human-Solutions (Fig. 5) and the face modeler *FaceGen* of Singular Inversions (Fig. 6). By the first example, three images of a person are acquired (two from the front and one from the side). By using the symmetry of the human body, the most important sizes of body are computed with sufficient accuracy from the silhouettes of the body. The extracted body sizes are used, in this specific example, for the preparation of mass customized dresses.

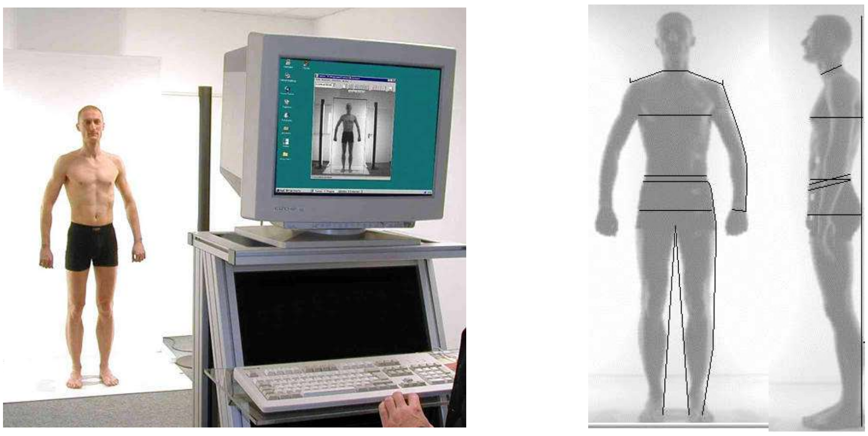

Fig. 5. 2D Full body scanner *Contou*r of Human-Solutions. Left: scanning equipment. Right: silhouettes images used for the measurement (images of Human-Solutions).

The second example shows the possibility to generate extremely realistic face models by using only two images of the person (from the front and from the side). The 3D computer model is generated manually with the help of user-friendly software tools. In this case, a real measurement of the human face is not performed. However, the produced 3D computer models are extremely photorealistic and completely adequate for applications as, for example, animation and computer games. Fig. 6 shows the software operating, the two used images and the resulted 3D face model. The big advantage of this combined technique (image processing and modeling) is its extremely lower price compared to real 3D measurement.

Fig. 6. Face modeler *Facegen*. Left: snapshot of software. Center: used images for the generation of the virtual head. Right: generated 3D face model with and without texture (images of Singular Inversions).

2.4. Required and useful software

For the completion of the overview on the actual state of the technology for the digitization of the human body, the required and helpful software has also to be described.
The raw data resulting by the scanning process can usually not be used in its original form. Mostly scanners are therefore provided with standard software for the visualization, for the treatment, for the exporting and eventually for the editing of the data. Fig. 7, on the left, shows for example the result achieved by *TriForm* full body scanner of Wicks and Wilson and on the right the result of a head scanning system of InSpeck. It can be clearly noticed that raw data of the full body scanner has to be processed. In the case of the head scanner, the result shown on the right has already been processed.

Fig. 7. Examples of 3D scanning data. Left: result of *TriForm* full body scanner of Wicks and Wilson. Right: head model (with and without texture) resulted by using InSpeck head scanner system.

Data compression plays an important role by the digitization of the human body. 3D scanning processes generate very large amount of data, e.g. the head model of Fig. 7 corresponds to about 27 Mbytes of data. Therefore, for an efficient and unproblematic storage, treatment and visualization of the data, adequate compression processes are required. These can be defined specifically to the different parts of the human body by considering the typical topology of their surface. We take the human face as example: every human face is round shaped, has a nose, a mouth, two eyes, etc. This basic information is used to reach strong compression factors without loosing the important features of the human face. Fig. 8 shows an example of a 3D face model at three different compression factors: the details of the eyes, nose, and mouth are conserved, whereas the data resolution in areas with fewer details is strongly reduced.

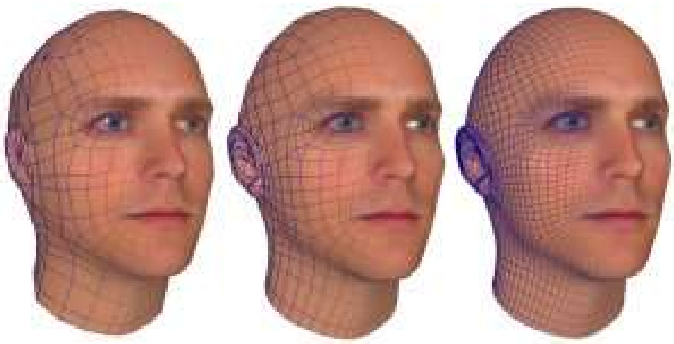

Fig. 8. Compression of a 3D face model, from right to left with increasing compressions factor (images of Singular Inversions).

2.5. Considerations

This was an overview of the actual state of the technology available for the measurement of the human body. Different methods and technologies exist, with their characteristics, their advantages and their disadvantages. The evaluation process plays therefore a relevant role for the selection of the correct and adequate method for a specific application. The requirements have to be firstly stated clearly and a list of criterions has to be considered:

- Part of the human body to be measured (full body, head, face, foot, etc.),
- Quality of the results (accuracy, resolution, texture),
- Hardware (costs, mobility, space requirement, handling),
- Process (invasivity, acquisition time, processing time, comfort).

An example in the case of face measurement shows the importance of such evaluation. Fig. 9 displays two face models generated by two different scanning systems: both virtual heads looks very nice, but they are very different indeed. The result on the left was achieved by using *FaceGen* Software of Singular Inversions. It resulted from only two images of the face. In this case, the cost of the software is below 500 US$. On the right of Fig. 9 is shown the result of the measurement of a person by using four scanning units *Capturor* of InSpeck. The cost of the scanning system is about 60,000 US$. With such different equipment costs it has to be clearly clarified for which reason a computer model is required and which scanning method best fit the application.

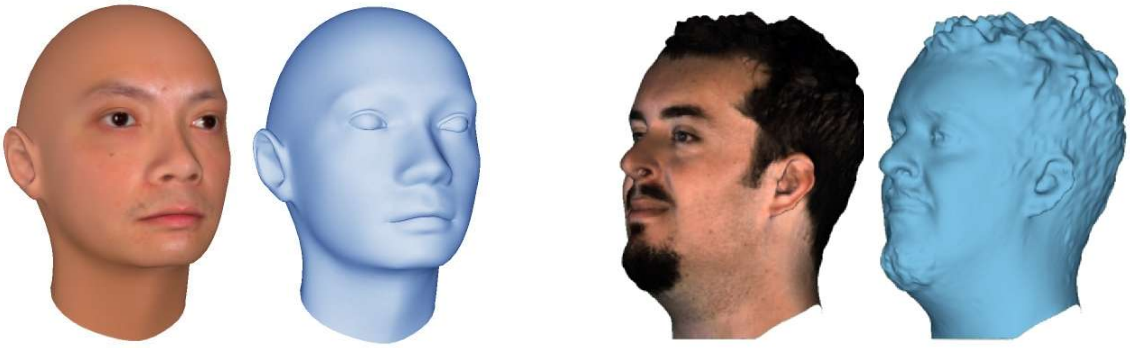

Fig. 9. Face models (with and without texture). Left: computer model generated with *FaceGen* by using two images. Right: computer model generated with four scanning units *Capturor* (images of Singular Inversions and InSpeck).

3. APPLICATIONS AND FUTURE EXPLOITATION OF HUMAN BODY DIGITIZATION

Various application fields exploit the digitization of the human body since many years. The different applications can be classified into two big groups, distinguishing them by their requirements:

- The first is more interested in the visual aspect of the results and regards mainly movie industry, animation, computer games, and virtual reality.
- The second, more interested in the quantitative aspect of the result, namely the measurement, includes ergonomics, anthropometrics, medical applications, and biometry.

For the first group, the results have to look real. The exact correspondence of the sizes of the real person with its virtual twilling does not play an important role. Fig. 10 shows three examples: realistic animations for commercials and for computer games (real soccer players are integrated virtually in computer games) and visual effects in movies.

Fig. 10. Application examples of human body digitization. Left: in realistic animations, commercial of foots sole (image of Montage Multimedia). Middle: in computer games, virtual twilling of Ronaldinho and Butt (image of Xbox FIFA 2004). Right: in the movie industry, Anakin Skywalker of Starwars Episode II (image of Starwars gallery).

The second group is less interested in the visual aspect. In this case, the precision of the results by the scanning process is important. Fig. 11 shows three examples: in the fashion industry for mass customization, in ergonomics for fitting exactly objects to human body parts and in anthropometrics for case studies and for analysis of human characteristics.

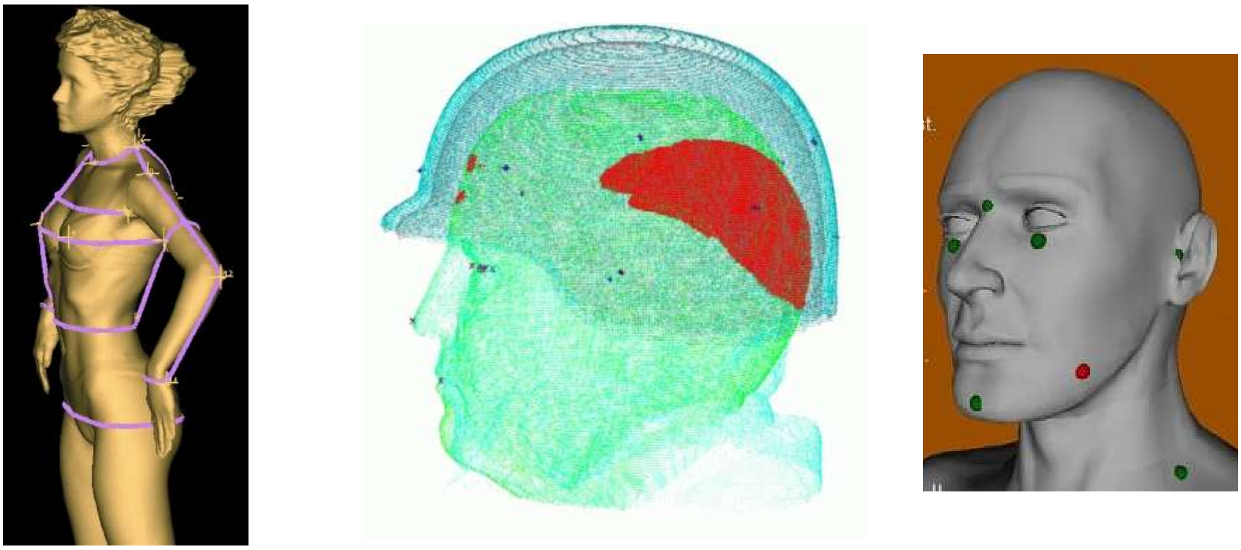

Fig. 11. Examples of human body digitization. Left: in the fashion industry, dresses can be produced by mass customization (image of Human-Solutions). Middle: in ergonomics, analysis of the fit of helms (image of Air Force CARD Lab). Right: in anthropometrics, landmark points describing the human face (image of NIST VR Lab).

Other branches benefit increasingly of this technology, as for example, medicine (e.g. plastic surgery, orthopedics, prosthesis construction), security systems (e.g. face recognition) or beauty industry. A large expansion of human body digitization is expected for the near future.

4. HUMAN BODY DIGITIZATION FOR BEAUTY / FASHION

4.1. Perfect styling thanks to human body digitization

Experts dealing with styling of persons are increasingly interested in commercial applications of human body digitization in their field. They wish to show their clients how they will look before they buy trendy dresses or before they choose for a beauty treatment. They also wish they could provide them with customized dresses at affordable costs. Fig. 12 shows examples of existing applications in this field. On the left is shown a snapshot of a virtual fashion show with digitized human models. On the center is displayed a digital customer card with stored body sizes, that were determined by full body scanning process. On the right is shown a web portal for on-line clothing shop, where different cloths can be tried on a virtual 3D person.

Fig. 12. Examples of exploitation of human body digitization for styling applications. Left: virtual fashion show. Center: digital customer card with stored body sizes. Right: web portal for on-line clothing shop. (Images of Digital Fashion, e-Tailor and Optitex.)

Fig. 13 shows other possible applications in beauty branches, namely hairdressing, accessories (e.g. glasses) and cosmetics. The examples on the left are unfortunately only 2D, i.e. a single image is used. By using 3D data the results will looks relevantly more realistic. Moreover, the image will be possibly viewed from different directions and virtual haircuts and accessories will be positioned more exactly. On the right is shown a 3D virtual make up (before / after).

Fig. 13. Examples of applications in beauty. Left: 2D virtual added haircuts and accessories (images of Cosmopolitan *Virtual Makeover*). Right: 3D virtual make-up, before and after (images of *Make-3D-Up* of Homometrica Consulting).

4.2. "Bad looking persons do not exist, but only bad styled!"

Beauty and attractiveness play an important role in social relationships. A case study of the university of Regensburg in Germany treated the relations between attractiveness and judged personality (for more information visit the homepage www.beautycheck.de). A clear and unbiased stereotype of attractiveness resulted from the study: «The more a person is attractive, the more she/he will be judged as successful, content, pleasant, intelligent, sociable, approachable, exciting, creative and diligent.». Especially in the multimedial society of today, the expert styling gains increasingly social significance.

The new technologies of human body digitization will soon be largely exploited in fashion and beauty. Everyone will be able to afford a perfect outfit with customized clothes and shoes. Additionally, thanks to human body digitization, expert styling will be available to everybody, satisfying all the prerequisites for a good look and well-being. Computer systems will soon be available to test, view and select styling elements on a 3D virtual model of ourselves. The entire impression of a new style (dress, haircut, make up, accessories) will be displayed on the PC monitor. A customer will be able to see how she/he will look like before realizing a beauty treatment (e.g. hairdressing, make up) or before buying a product (e.g. dress, accessories). The customer will so be able to identify himself better with its new appearance.

The technology exists and is mature to realize such applications. Scanners exist for the digitization of the full human body, of the face, of the feet, and of other body parts. Software exists for data compression, for data treatment and for data visualization. A smooth utilization of 3D solutions is possible on normal PCs. Software for the exploitation of 3D data for different styling applications are already available. The future of human body digitization for fashion has already begun.

5. CONCLUSION

In this paper, we presented the actual state of technology for human body digitization, describing the different methods commercially available. We gave an overview of their differences and characteristics and expresses clues for the selection of the adequate solution for specific applications. Practical examples of commercial exploitation of human body digitization were also presented and new interesting perspectives for beauty and fashion were introduced. A large expansion of human body digitization is expected in the near future.

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