The application of 3D scanning as an Educational challenge

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Since 2001 we teach students about 3D scanning and 3D printing because of a growing demand in society. This paper will show which methods were explored in the area of evaluating the fit of human-product interaction at Industrial Design Engineering and how 3D scanning and 3D printing did make a difference. Ergonomics plays a big role in this process, however in a different and advanced way than before.

In general we still teach a human centred design approach in one of the largest schools in industrial design engineering in the world.

Practitioner Summary:
This paper is about the experience of a large school trying to teach ergonomics including 3D scanning and 3D printing as tools.

Keywords: 3D Anthropometry, Industrial Design Engineering, Ergonomics, Human Factors

1. Introduction

Our products and services are focussed on those that are frequently used by the consumer like a bike or a camera or a car or a navigation system. During the design process and after an analysis of the usage situation in a certain context, product models and later prototypes are used to be tested by a sample of (simulated) users.

When 3D printing became possible more and more students made there the models and prototypes in a 3D CAD software like Solid Works and sent them to a 3D printing company. Later we achieved 3D printing machines ourselves for small products. And since 2000 the students can use our online interactive tool DINED.nl to explore the variation in human body dimensions in 1D and 2D and 3D. The 3D human models are simple wireframes and have a lot of shortcomings compared to a sample of real living subjects. But after 3D scanning did become acceptable, we started teaching how to use the 3D scanners in demonstrations, and workshops where several types of scanners were available.

After that the number of requests to use the 3D scanners was boosting. As staff we learned a lot from the questions and from the attempts to scan a simple hand or foot or face, while using a product. We learned that a dead body part in an anatomical lab is must easier to scan that a hand or foot of a living subject. We learned also there are several 3D scanners out there that have each pros and cons for a large variety in prices (http://www.3dbodyscanning.org/).

Apart from the abovementioned experiences with students and projects, we also experienced different software solutions for the road from a 3D scan to a 3D design. Sometimes you need up to 8 different software programs to be able to use the scanned data in your digital design (Zhang, 2005 and Ball, 2010) and finally we experienced it is very useful to interact continuously from the digital world into a physical model into a better 3D scan of a product model into a better 3D digital design and first test this with a digital human and at last use a sample of living humans to test the final prototype (Krouwel, 2010).

Some products will not be produced in series in stock because the product will only be 3D printed after a consumer has bought the product and it is customized on his/her body shape and size (Molenbroek, et al, 2013). This causes also a new way or marketing and purchase. Because now the customer will in the near future use his or her avatar (a copy of the body of the customer) to test the fit with a product in the digital environment of the shop.

When the digital version of the product fits with the avatar and the customer also can judge the colour, size and shape, the customer will decide to buy and pay. The product is sent to the customer to enjoy the usage. Knowledge about ergonomics and human factors is needed during the analysis, the concept and the
embodiment phase of the design process. Only the traditional ways will need to shift to follow the advance changes in technology.

2. Faculty Industrial Design Engineering

Faculty Industrial Design Engineering started as an initiative from a Dutch Minister after the second World War, who initiated a committee to prepare a school of industrial design at university level. The reason was the growing import of Italian and Scandinavian consumer products. He thought the Dutch should also have a school that thought lessons about how to integrate art and technology. The committee travelled around the world (USA, Italy and Denmark especially) and started a school of Industrial Design in Delft based at the faculty of Architecture. First it was called Technical Industrial Design (but people called in Industrial Design or just Design) and later Industrial Design Engineering (and people still call it just Design) to avoid it was only about Design. The basic pillars were Engineering, Design, Ergonomics and Marketing. For more than 25 years this so-called butterfly model with 4 wings of equal size sustained. Each of the 4 departments had more or less the same weight: budget, staff and content in the courses and research.

Industrial Design Engineering is

![Figure 1: Equal contribution of 4 wings of the butterfly model Industrial Design Engineering](image)

Later after more than 30 years the butterfly model was evaluated into the triangle Human-Technology-Business (figure 2).

Our way of working

![Figure 2: Model of Industrial Design Engineering in Delft](image)
This also resulted in having 3 departments:
- Industrial Design that teaches and does research into people and their desirabilities, but also human factors and ergonomics, usability and contextmapping, positive design.
- Design Engineering that teaches and does research into feasibility but also in materials, strengths, sustainability, smart materials, internet of things
- Product Innovation and Marketing that teaches and does research in viability but also in consumer research, branding, new product innovation.

3. Teaching Master Course Advanced Embodiment Design (AED)

For the benefit of this Ergonomics conference one course is taken as an example.
AED is taken because the first author of this paper was asked to integrate ergonomics knowledge into this course. AED is a sum of 6 former smaller courses of 3 ECTS and a project. An ECTS is a European Standard for an Educational unit of 28hours studying for an average student. A whole year is 60 ECTS and this ECTS makes it easy to exchange students between universities, Currently many course are 3 ECTS but AED is a so called monster-course of 21 ECTS. We have two of them in the Master. The reason is streaming and higher effectiveness of studying. If a student starts this course he or she will do his or her best to end it successfully. At least that is what the our educational advisors tell us. The disadvantage is the complexity in organisation. In this paper only a small description will be enough to give the impression of complexity. Although one professor is responsible, most work is done by the coordinator, mostly a young lecturer. Apart from them there are 7 experienced lecturers and many colleagues to support the tutoring of the course. We were trained 12 months before the course started each month half a day. The ergonomics teacher explained his teaching material to the others and vice versa.
Apart from the 6 sub-courses of which one is ergonomics there is also a project to run: to develop a working prototype for a company or a running research project of the University staff. The students go for it with 25 groups of 5 students per company. One group was the Deltabelt, which was a belt for around your waist, but it includes sensors to measure continuously your waist circumference. That group liked the research so much that we proceed and will publish a paper about it soon. Each group has a coach for weekly progress meetings and a research tutor also for a series of meetings to conduct the necessary ergonomics investigation; mostly a combination of literature research/interviews with experts and some experiments.
Another group developed a principle of a facemask for children based on the outcome of the PhD research of the 2nd author who 3D scanned 300 children’s faces, with a 3DMD scanner. In this way the PhD –project is supported and intertwined with the education to benefit both the student group, so they have useful scans and the PhD project that has a proven principle to work with(Goto et al, 2013).

4. 3D Scan related materials for AED

After several of our and other peoples projects in the last 15 years we concluded it is interesting material for students to work with. The following projects came in our line of sight:
The Caesar project (Robinette and Daanen,2006) and website http://store.sae.org/caesar/
The PhD–project of Bing Zhang in our group (2000-2005), in which 200 3D Caesar scans were used via an ANN Neural Network to predict a sitting posture from the standing posture (Zhang,2005 and Zhang et al., 2010)
The PhD-project of Roger Ball (2005-2010), in which 2000 Chinese head forms were 3D scanned with a Cyberware red laser scanner (Ball,2010 and Ball et al.,2010)
The Fastest Swimsuit project in which we did a longitudinal study to 3D scan the shape variation of 8 Dutch female top-swimmers in advance of the Olympics in London in 2012 in relation to the design of the swimsuit and their performances in the water (Van Geer et al.,2012)
The first phase in the project of Lye Goto to scan 300 children meant for the design of a ventilation mask with the 3DMD scanner (Goto et al. 2013).

Another large piece of knowledge and experience in the field of 3D anthropometry came from WEAR-group the World Engineering Anthropometric Resources (www.bodysizeshape.com), in which each of the 15 founders shared their experiences in the annual meetings.

5. Scale of the School: Staff and students for AED

With 300 freshmen of 17 and 18 year old young adults for the first time living on their own each year and more than 2000 in total the faculty has learned to organise the teaching. In IDE there is a Bachelor curriculum of 3 years and 3 Masters of each 2 years. This means a tight schedule is necessary for all materials and classrooms, because the next hour the room can be needed for another group of bachelor or master students. It is all programmed in a master schedule one year ahead. No deviation is possible because of the numbers. The students and the professors follow the schedule after it is accorded.
by the Director of Education. Holidays and other private reasons can’t modify the schedule although a colleague can take over when there is a good reason like illness or a funeral.

Innovations each year
The last few years we experienced each year some innovations in the available 3D scanners; they became better and cheaper. So more chance for an educational institute with a low budget to achieve them.

Luckily there were some research projects with third money stream, so the equipment could be borrowed from those projects for educational purposes for a short while. This was enough to demonstrate the equipment to the students and to make them familiar with it. The biggest problem was always to have enough scanners on the scheduled day and to have licenses for software to handle the 3D scan, make it smooth, fill the holes, and send them to a CAD–software. We have experience with: Geomagic to modify 3Dscans more advanced like double curved surfaces like the room behind the human ear, Artec-Studio to do the first modifications of the 3D scan, SolidWorks to receive the .stl files from Artec or Geomagic and to use them to create a product that fits the 3Dscan (of a body part). Also Artec is useful for showing the ease: the space between the product and the human skin (see Figure 3 about the swimsuit project).

6. Moocs and online learning
A new phenomena arises because more and more courses need to be available in a MOOC, a Massive Open Online Course. This means large numbers (10-50 thousands or more) of students in different countries doing a course at home behind their computers. See EDX.org for an overview of available courses. Faculty Industrial Design Engineering also has include the course ‘Delft Design Approach’ to show the user centered design methods. When 3D scanning would become an online course than several challenges arise:

-How to let the student at home experience the 3D scanning. We can expect it will be possible in near future to rent a 3D scanner at a company and having an instruction video online. Or using a smart phone with an app like on Poikos.com.
-Thereafter the necessary software licenses should be made available for the time needed for the course.
-3D printing can already widely on the globe be done via www.3Dhubs.com

7. Growing insight
More and more design students seem to work iterative from a moment in the physical world to make the first shape in clay, 3D scan it and fit it with a digital user or relevant part of that user, like a small and large hand. Thereafter improve it for the next version and 3D scan it again, mill or 3D print it and test it with a sample of real users and make the next step towards an early prototype. See figure 5.
Figure 5. Examples of pieces in a iterative stepwise design process of a child ventilation mask and a multifunctional syringe for a dentist.

Figure 6. Final Master student Pamela Leon (2014) with her 3D printed orthoses. Plugin Grasshopper inside the modelling software Rhynonceros makes it possible to create holes in the cast and vary the thickness and the shape of the wires around the holes. (Figure 6).
7. Future perspective

Expected is that we have in the near future all our avatars in the cloud. Because than it is possible to fit your virtual clothing and equipment on your 3D avatar which will be a copy of your last upload of a total body scan. Currently people purchase online 5 pieces of shirts or dresses and return free of costs all that don’t fit. This process costs a lot of money but companies accept those costs because they make or assume soon to make lots of money that compensate those costs.

Suppose you have made a 3D scan like this on Bodyhub https://www.bodyhub.com/#/ that moves and has the same shape and dimension like you have. There is an interface in which you can upload the digital version of equipment of clothing you consider to buy. The software helps you to show how it looks on your body and your avatar even walks around, makes squats or reaches with both arms to the fingertips and other critical movements for your purpose like in sports or profession and so you can see if it still suits you.

If you are satisfied buy it and write a positive review if it really does in the physical world at your home. For other customers your review is important as the company also realizes and will give you a discount next time.

Do you have an own avatar in the cloud? Maybe not yet, but maybe you have essential pictures and documents already in the cloud so you can download them from the internet wherever you are. So an digital copy of yourself might be not so far away. Would it not be easy for your medical doctor too if he or she forgot how you looked he or she could have a license for using your avatar. It would be right if the ownership is where it belongs(you) but you can decide to let others use it under your condition.

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