Fitting fashion using the internet:

research findings & recommendations

Project: Fitting fashion using the internet (Passende kleding via internet)

Projectnumber: RAAK.MKB04.004

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VU / HvA

Contents

1 Introduction

The goal of the project 'Passende mode via internet' (fitting fashion using the internet) is to reduce the number on undesired garment returns. The Netherlands is currently record holder in the number of returns of goods with fashion being most prominent (https://www.eshopperbarometer.dpdgroup.com/chart.php). Inappropriate fit is a main argument for returning the goods. The method to achieve the goal to reduce fashion returns in this project is to identify the preferences and body dimensions of the customer and translate this information into the selection or production of a best fitting garment or other fashion item. Five solutions were identified that are treated consecutively in this report: 1) smart questions answered by the consumer using the internet so that an image of the body dimensions of the consumer is retrieved (and ultimately the correct size of the garment can be supplied) 2) the use of a smartphone or tablet to derive body dimensions 3) the use of 3D body scanners 4) convertors or plug-ins that ask for an existing garment that fits well and converts this information to body dimensions. Finally, a brief exploration of the possibilities of 3D printing of garments is given.

The report is based on literature search, web search and participation in the international conferences on whole body scanning in Lugano. The available information is clustered and placed in context. It is realized that the information is not complete since the companies providing info is rapidly increasing. However, it may be a good starting point for fashion companies looking for new technologies, or for teachers education students in fashion.

This report is in English in order to be able to receive additional input from non-Dutch speaking experts. The report is unrestricted for distribution, and may be used for educational purposes. The sources are mentioned as far as they could be identified. The author thanks Rens Tap and Lucie Huiskens, Kim Walraven and Lisette Vonk for their contributions.

2 Smart questions

The idea behind asking smart questions is that the customer transfers information through a user friendly interface over the internet to inform the supplier with data to estimate the body dimensions, preferences and/or body shape of the customer.

2.1 Clothing sizes

Most current websites ask customers to enter the garment size (e.g. S, M, or L). However, garment sizes differ considerably between suppliers. There is no current standard regarding the relation between body dimensions and garment dimensions that is adopted by all suppliers. As a consequence, sometimes the consumer has size S as best fit, for another supplier it may be size L. Fig. 1 gives an example. 27 Firemen had to select the best fitting garment size of five different brands (Krul, 2004). Obviously, the difference between suppliers is considerable; for supplier E for instance the garment sizes were smaller than for supplier B. Inter-individual differences are obvious as well: Subject 2 for instance opted for size L for

supplier D and size M for supplier E, while this was reversed for subject 6.

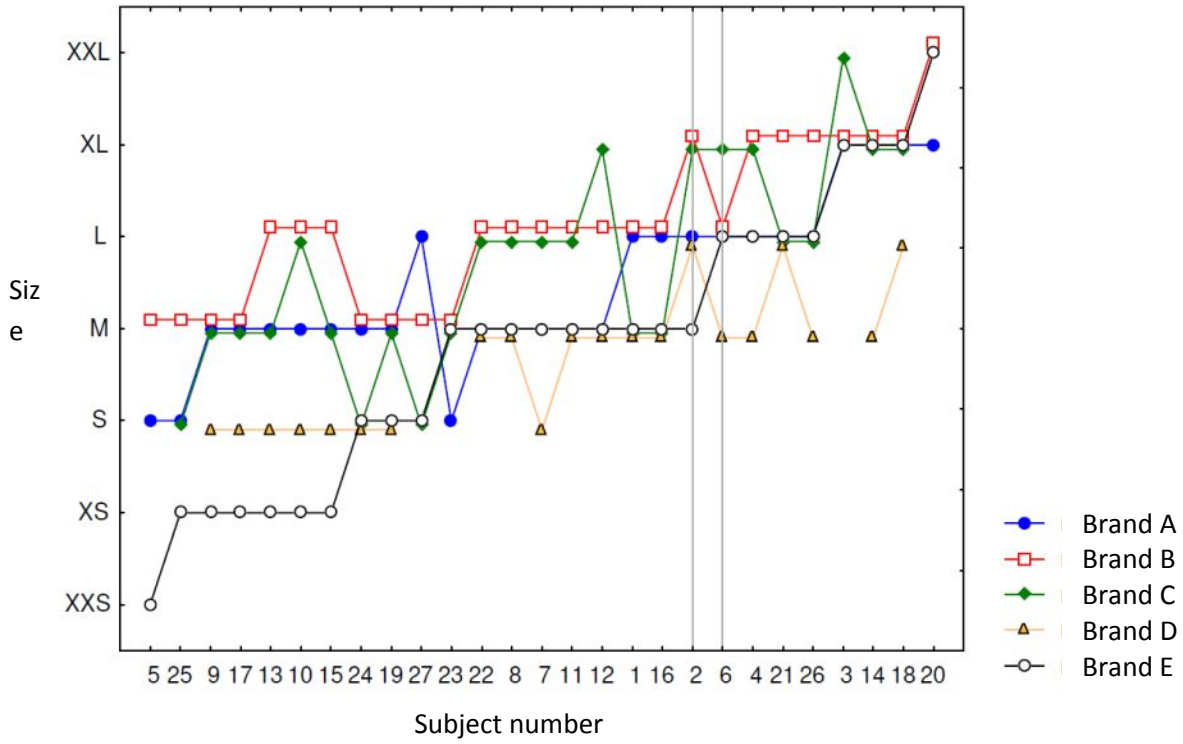

Fig. 1 Best fitting fire resistant jacket size for 27 subjects. Please note the differences between brands.

Jeans do have a relation between body dimensions and clothing dimensions, in which the waist circumference and inner leg length in inches are used as size indicator. Although considerable variation exists in sizing of garments, the average values of clothing sizes do correlate with overweight indices (Hughes, Schouten, Goldbohm, van den Brandt, & Weijenberg, 2009).

2.2 Basic body assessment

Some body dimensions are well-assessed by most subjects, such as body weight and stature. Also, the age and gender is known and this relates to body dimensions. Just using these values may already give a rough estimation of the body shape and some other body dimensions such as inner leg length. Adding collar size, known by most men, leads to a fair assessment of body dimensions essential for shirt design. Bivolino (www.bivolino.com) employs this technique for men's shirts. They extended the technique for female blouses using bra size as an input (H.A.M. Daanen & Byvoet, 2011). The estimated upper body dimensions are transferred into an individually tailored clothing pattern.

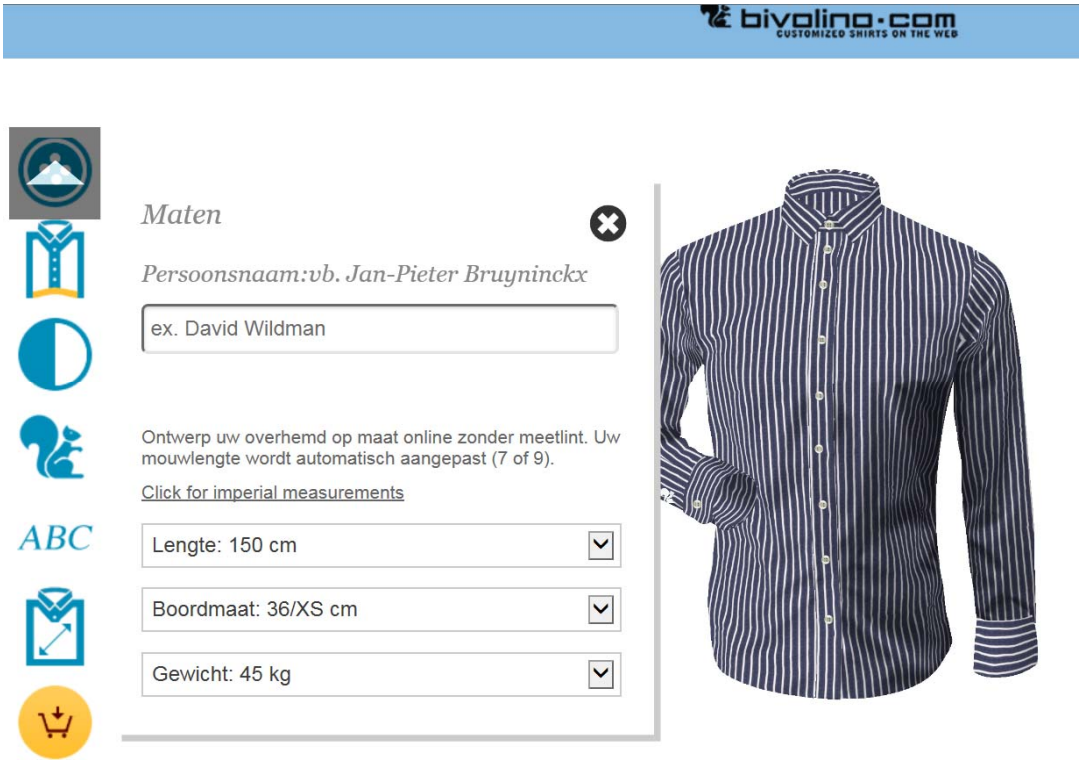

Fig. 2 Example of an interface to ask for body dimensions (lengte=stature; boordmaat=collar size; gewicht= body mass).

It is known that estimated weight and stature does not always correspond to measured values. Heavy people have the tendency to underestimate body weight and small and older people have the tendency to overestimate stature. These systematic over- and underestimations are published and may be used to correct the estimated values (Krul, Daanen, & Choi, 2011).

Sizestream (www.sizestream.com) recently introduced an app in which the user can introduce the basic body dimensions (gender, age, weight and stature) and the resulting avatar is visualized on a mobile phone or tablet. The shape of the avatar can be edited and improved based on subjective information.

2.3 Self-assessed body dimensions

Another option is to ask people to assess the length or circumference of certain body parts without measuring them. For instance a small slider on the screen can be used. The idea behind this method is that people continuously compare themselves to peers and experience in shops how they compare to body dimensions of other people. This implicit reference frame can be quantified by asking smart questions or use tools like sliders. There seems to be a fairly good relation between self-assessed body dimensions and measured body dimensions, e.g. for arm length (H.A.M. Daanen & Byvoet, 2011). At the bivolino website (www.bivolino.com) customers can indicate if they experienced body dimensions or shapes deviating from normal, and if so they can indicate which. It is better to ask for clear body dimensions than to ask people to compare themselves to shapes like rectangles or triangles. Also asking

if someone is pear shaped or shaped as a hourglass (e.g. http://shopyourshape.com/body-shapes/) does not yield useful info.

Sizebuddy (www.sizebuddy.com) is developing a passport in which essential body dimensions are stored. When the internet is searched for garments, only the applicable sizes are shown, saving time and money.

It may help if the body is visualized on the screen and if the body dimensions can be adapted by the user. Stylewhile (www.stylewhile.com) is an example, as well as virtual manikin (www.). In Amsterdam, the company MimicMe was active for a while, but this is no longer the case.

Several companies ask smart questions on other topics than body dimensions in order to propose garments that are in line with customer interest. https://www.silksage.com/ for instance wants to know if you are always in a hurry or not, if you are creative or not and uses this information in the proposal of fitting garments.

2.4 Self-measuring of body dimensions

Asking a customer to measure himself or herself may lead to inconsistent or erroneous results. For instance the tape is old and stretched, the subject measures at the wrong body location, or reads the length of the tape at the wrong side. Therefore, good instruction and some training is imperative. Traditional body measurement methods are described in ISO standards. ISO 8559 is dedicated to body dimensions for clothing design (http://www.iso.org/iso/catalogue_detail.htm?csnumber=15821). Reproducible human body measuring requires training. ISAK (http://www.isakonline.com/courses) supplies this training. It is good to realize that training all customers is not achievable. Some instruction videos are available on the internet that may reduce error e.g.
https://www.youtube.com/watch?v=w7njhM0jMF8 or
https://www.youtube.com/watch?v=rtKglFA2NJc or
https://www.youtube.com/watch?v=A5IwwuK5VmQ.

Otto (www.otto.nl) is an example of a website where customers have to measure themselves.

The Besized application (www.besized.com) is a personal and brand specific size advisory tool for children's apparel that benefits both consumers and web shops. The customer enters the birth date of the child and the stature and weight. Based on this information the garment sizes are indicated. The idea is that the shopping experience of the customers will improve since Besized will help them to pick the right size. This way it will overcome the size uncertainty hurdle that in most cases prohibits a consumer to purchase. The idea is that Besized will significantly decrease the return costs and improve a websites image. Besized uses scientific data (TNO / Netherlands Organisation of Applied Scientific Research). Besized has a large database with representative samples of children's measurements in The Netherlands and specific size tables of several brands. Using these datasets in a dedicated model leads to the size recommendation for children's garments.

3 Smartphone or Tablet

Several companies offer apps on a smartphone or tablet that make photos from which body dimensions can be deducted.

IBV (Institute Biomechanics of Valencia) produced an app called Kidsize (www.kidsizesoluition.com) that asks for a frontal and sagittal picture as input, as well as information on age and stature. Stature is used for scaling. The app is developed in a EU project. The profiles are linked to a 3D scan database of 800 children. The tool is thoroughly validated, and a link to garment size is made using 1100 fit tests with children. The fit assessment is done by independent experts and parents. The size recommendations are good; it is one of the best tools available. They are expanding the app to adults. The results are accepted for publication in the Elsevier journal 'Data in brief'.

Another company that follows this line and employs the same technology is QuantaCorp (www.quantacorp.com). The first draft was evaluated by Vonk and Daanen (Vonk & Daanen, 2015). A new version is available that may be evaluated in this project. In a more recent evaluation, the QuantaCorp system was used to predict the best fitting size of a Jobe Unify vest https://www.jobesports.com/jobe-unify-vest-men-black-244917102/ that was fitted in 22 males and 39 females. The QuantaCorp size prediction was close to the expert for males and slightly bigger for females. Submission of this study to a scientific journal is planned.

Astrivis (www.astrivis.com) uses a smartphone for 3D scanning. It is nice for objects, but seems less suited for body (parts). Development is continuing. Netvirta (www.netvirta.com) uses a smartphone to scan (parts of) the body as well.

Nettelo (www.nettelo.com) uses a smartphone to determine body dimensions and interact with the user.

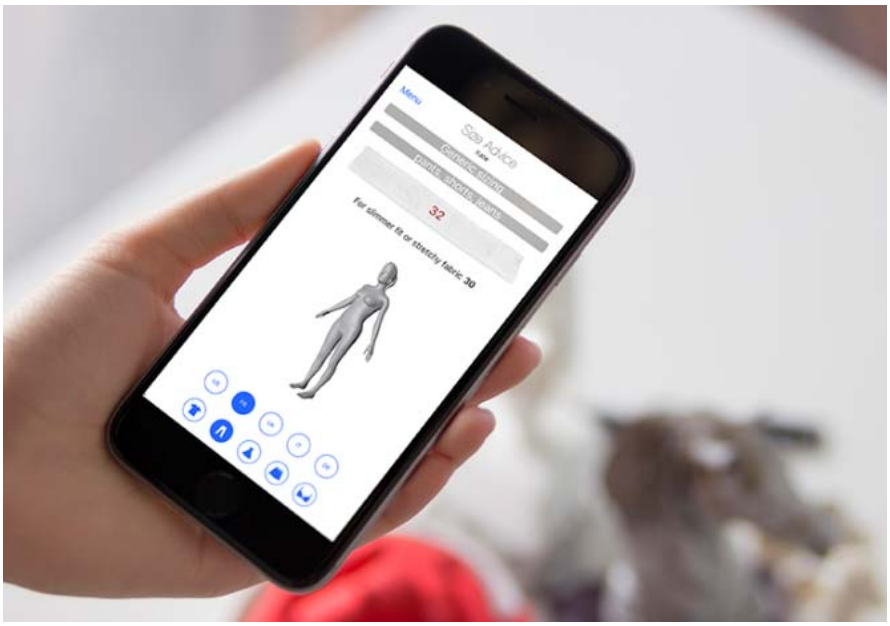

Fig 3. An impression of the Nettelo app.

https://www.fision-technologies.com/ uses a smartphone to determine essential body dimensions for garments.

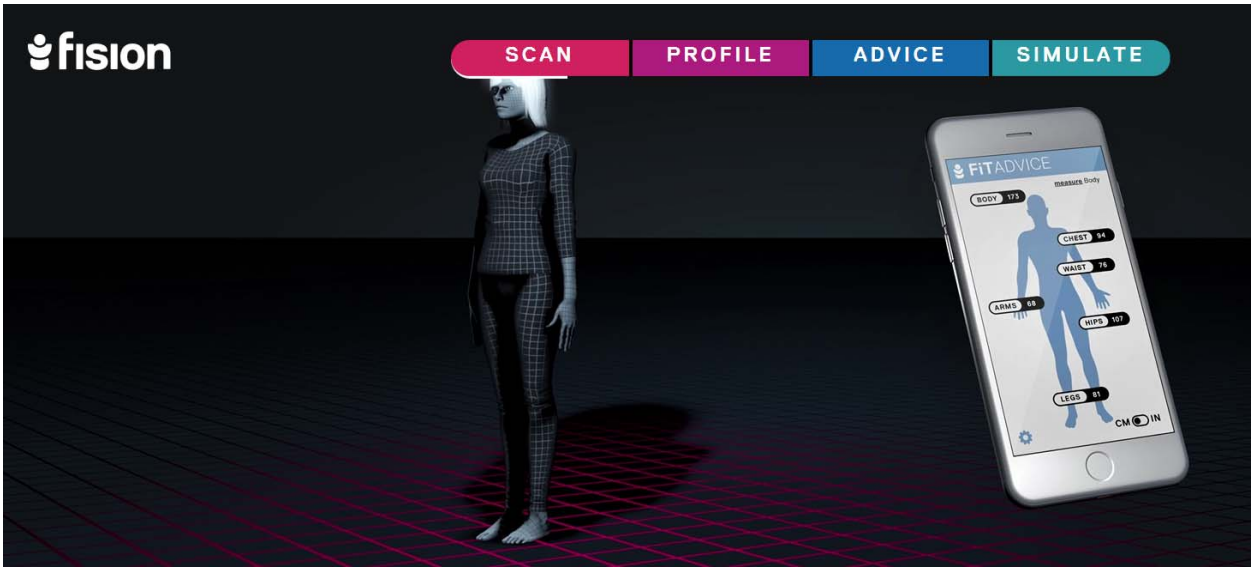

Fig 4. Screenprint of the Fision app.

3D about me (www.3dabout.me) uses an app to scan the feet and supply the fitting size of the shoe. They have a database for major brands on the conversion of foot dimensions to shoe dimensions and currently also work for the Dutch military. Another company active in 3D shoe fitting is www.safesize.com.

Metail (www.metail.com) offers virtual fitting on a copy of your body visualized on a smartphone or tablet. They offer the service to photograph the garments and then the customer can see it on her or his body. Yannis Douros, previously working on SizeUK, works for Metail. It is owned by the same Hongkong company that has major shares in Sizestream.

A new concept is Fitbay (https://fitbay.com/). If a garment fits you perfectly you send this information to a friend with similar body dimensions using the fitbay app. The idea is that this way clusters of similar body shapes will develop that notify each other and thus looking for the right size becomes easier.

http://mysizeid.com/ algorithms to capture a person's measurements using their smartphone sensors, without the need to use a camera. You move your smartphone over the body and thus measure the body dimensions.

Fig 5. Mysize uses the sensors in the smartphone for measurements, not the camera.

The ZoZo app (https://zozo.com/nl/en) measures your body dimensions is a suit that is sent to the customer for free. The app is voice operated and takes snapshots of the customer in 12 positions that correspond with 5, 10, 15, 20 .. minutes on a clock. This suit is evaluated by the author and reproducibility is high (Fig. 7).

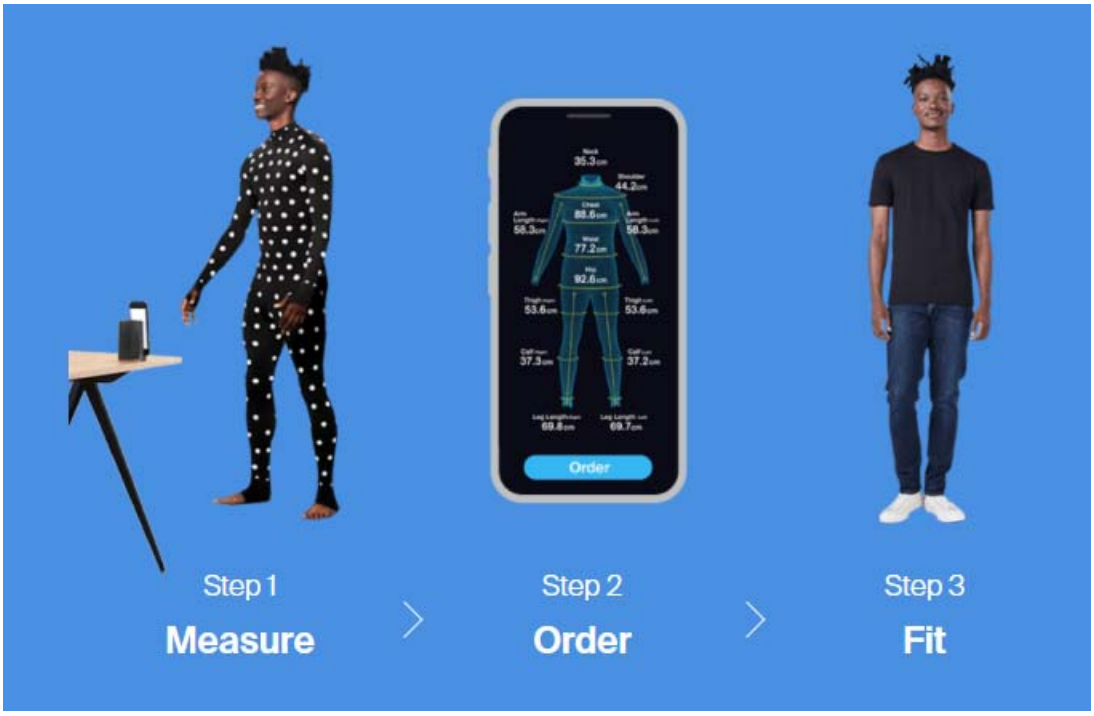

Fig 6. The zozo suit and app

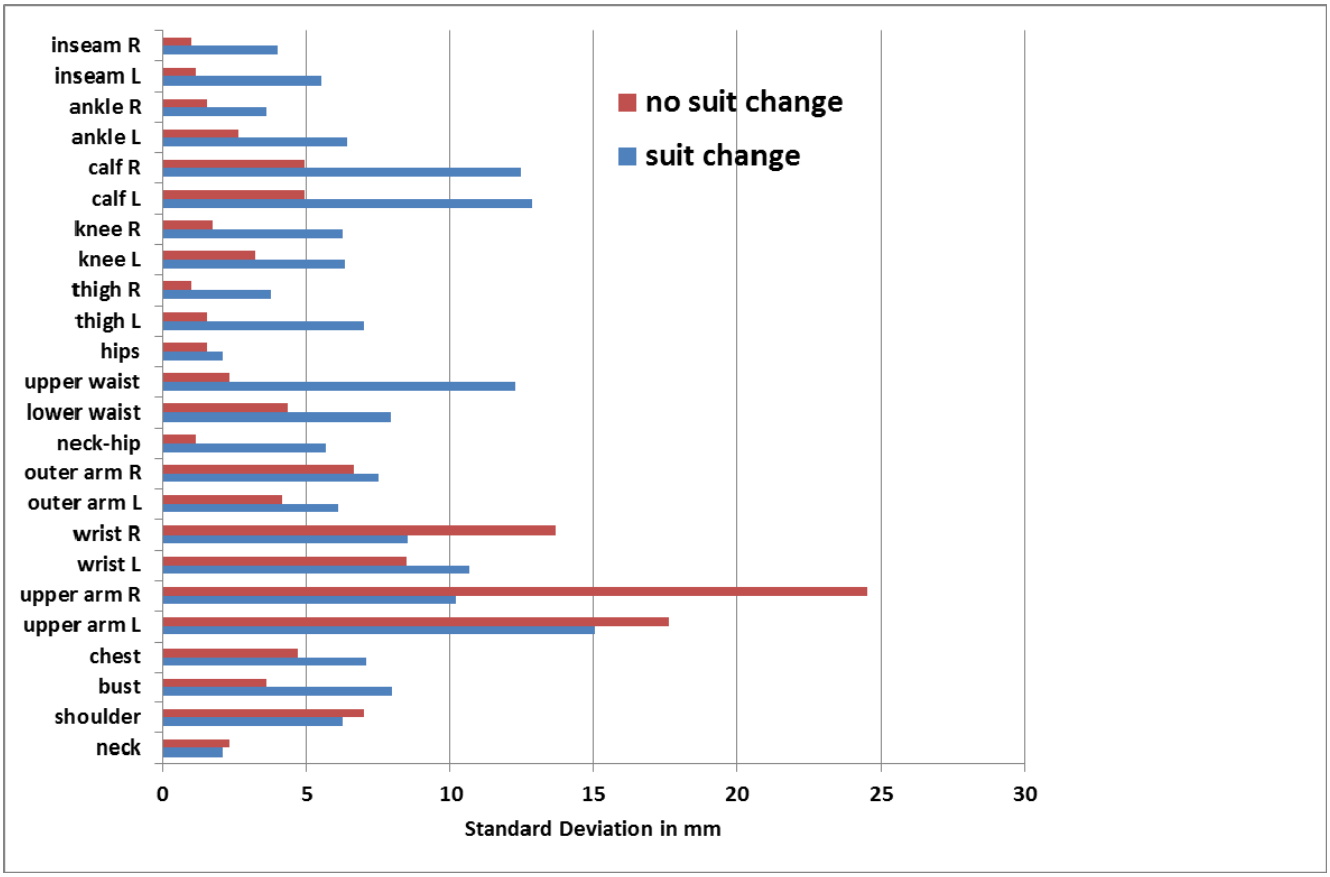

Fig. 7 Reproducibility of measurements for the ZoZo system. The author donned the suit 3 times (suit change) and measured 3 time in the suit (no suit change). Please note that the errors are relatively small with the exception of the arm (probably due to occlusions effects).

4 3D scanners

3D whole body scanners started to appear on the market in about 1995. The latest reviews of Daanen may serve as a review (H. A. M. Daanen & Ter Haar, 2013). The newest developments are discussed in this document, mainly based on presentations during the 7th international 3D scanning conference in Lugano.

4.1 hardware

4.1.1 Whole body scanners

LASER

Laser based scanners are increasingly replaced by stereo photogrammetric scanners. Vitronic (www.vitronic.de) is in the market with their Vitus laser scanners, marketed by Human Solutions. Price for their top systems is about 100 kEur.

STEREO PHOTOGRAMMETRY AND PATTERNED LIGHT PROJECTION

On the high end 3DMD (www.3DMD.com) offers high quality stereo photographic scanners with up to 60 Hz scanning rate. These systems have the potential to replace current 3D motion tracking systems like Vicon. The systems are transportable and have two software packages to process 3D data in time. The systems are available in several locations in the world; in the Netherlands Radboud University, Erasmus University, Delft University and others employ these systems. Prices of the new Vexellaris system are about 180 kEur, but a fully equipped system can easily pass 300 kEur. The most sophisticated system is available in Tubbingen (Germany) where Michael Black is the main investigator. The 4D (3D in time) capabilities are applied in garment sizing applications for instance to visualize the clothing/body interface during extreme body positions, or sport specific movements like golf.

Fig. 8 A scan of the 3DMD system. The system can make several scans in one second.

Botspot (www.botspot.com) uses normal Canon cameras (1200 series) to acquire stereo photos. The system is flexible. A system with 64 cameras is priced at about 140 kEur. New is the use of autofocus, so that small and large object can be scanned with high accuracy. When necessary, a random pattern is projected on the object to increase the image matching. The pattern is not visible on the final scan.

The portable full body scanner ScanLounge by Scanologics (www.scanologics.com) in Amsterdam is equipped with 244 IR camera's and 8 projectors to produce good quality 3D full body scans. Fully automated previews of the scans are send to the customer in order to make online purchases.

Fig. 9 The Scanologics scanning booth

Vialux (https://www.vialux.de/3d-koerperteilscanner.html) is a German company manufacturing 3D body scanners mainly for medical use.

This technique is very similar to the system employed by th3rd (www.th3rd.com) in Amsterdam. They are capable of generating very precise copies of human bodies, as shown in their study of Tom Dumoulin in a cycling position.

The company 3D elements (www.3delements.com) showed a dome in Lugano in 2016 with a multitude of low cost IR camera's to produce good quality 3D body scans. The customer can make a 3D photo and a payment system is included.

The systems described above have fixed camera systems. Recently, a project was executed at VU University in which students moved a single camera around the hand and were able to establish an excellent 3D model using simple low cost software (Agisoft Photoscan - http://www.agisoft.com/) that stitched the images to a 3D model (Fig. 10).

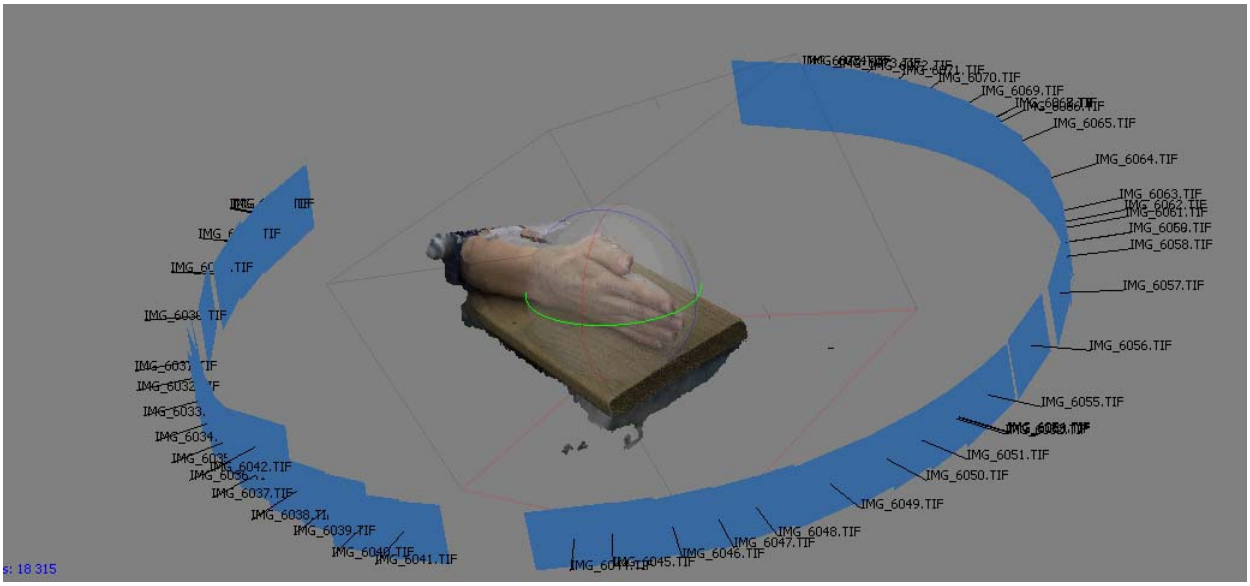

Fig. 10 Photo of a 3D hand model made by a single camera. The blue rectangles show the position of the camera when a photo was made.

Another system that converts photo's to 3D models is available at www.cappasity.us. This shows that since cameras and software get less and less expensive, the actual cost of an accurate 3D photogrammetry system can be very low.

KINECT (INFRARED) BASED

Sizestream (www.sizestream.com) showed their updated system in which Kinect sensors were replace with intel systems. They still sell the Kinect based systems that is operational at the Amsterdam Fashion Institute.

Profactor employs a 500 US$ hardware scanner using a turntable and a Kinect.

Styku (www.styku.com) sells a simple 3D body scanner in which the subject stands on a turntable. The system was initially advocated for improvement of clothing fit, but the sales were disappointing. Now, the system is marketed to follow body shape changes due to physical training. They claim to have sold over 300 systems worldwide. They closely work together with the company fit3d (www.fit3d.com).

Emaldo (www.emaldo.com) employs a Kinect scanner to generate a 3D copy of your body. Clothing can be visualized on the body online.

SCANNER HUBS

The scanners mentioned above are generally too expensive to place in retail stores; most of these systems are used in research. However, some attempts are undertaken to make a website with public scanners that can be used for the public. The same is done for 3D printing (www.3dhubs.com) and this is

very successful. Since printing is far more time consuming and scans can be made quickly, 3dscanshubs may become a success as well (see https://www.3dhubs.com/talk/thread/scanning). I have not seen a company yet that takes up this challenge.

4.1.2 Handheld scanners

A low cost handheld scanner is the sense scanning system from 3D systems (http://www.3dsystems.com/shop/sense). It takes time to scan an object; it works better on a turntable. The scanner can be mounted on a tripod for photo cameras. Scanning a whole body is a challenge.

The handheld scanners from Artec are most well-known (www.artec-group.com) and in use in the Netherlands at the company body issue (www.abodyissue.com). These scanners are accurate and can be used to copy the whole body; however it takes time and movement artifacts have to be prevented (the subject has to sit still).

4.1.3 Smart mirrors

Smart mirrors are mirrors with additional information on top, often based on images taken by a camera (sometimes 3D). This is also called mixed reality or augmented reality.

Some examples of virtual mirrors are:

- VandeVelde (brand Rigby & Peller): https://www.youtube.com/watch?v=iYgYBvvNWtw
- sweetfit http://sweetfit.fr/
- https://design-milk.com/naked-labs-3d-body-scanning-mirror-offers/ offer a mirror with a built in scanner.

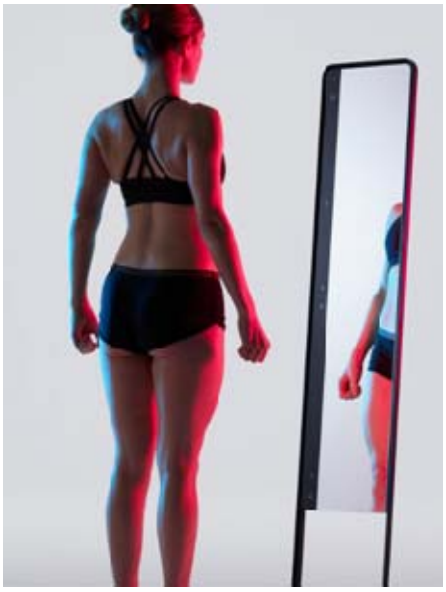

Fig 11. The Design-Milk integrated mirror and scanner

As a global leader in virtual try-ons of eyewear in augmented reality, FittingBox (http://www.fittingbox.com/) provides sales aid solutions on the web or in stores. It is only for faces.

4.1.4 Overview

A recent overview of scanning systems is shown in Table 1 (Courtesy of Allan Keefe, Canadian forces).

Table 1 – Overview of 3D body scanners with link to their website.

No.	Scanner	Company Name
1	TC2-19B	**TC2**
2	MyBody	**Styku**
3	Full Body	**Instituto De Biomecanica De Valencia (IBV)**
4	Mobile 3D Body Scan	**Nettelo**
5	Artec Eva	**Artec3D**
6	Sense 3D Scanner	**3D Systems**
7	VITUS 3D BodyScan	**VITRONIC**
8	HANDYSCAN700	**Creaform**
9	MTailor	**MTailor**
10	SS20 3D Body Scanner	**SizeStream**
11	ShapeScale	**ShapeScale**
12	Naked	**Naked**
13	Twinstant Mobile Full Body 3D Scanner	**Twindom**
14	Texel Portal	**Texel**
15	OPTAone Botscan	**Botspot**
16	VECTRA 3D	**CANFIELD**
17	ProScanner + Success Hub	**FIT3D**
18	BodyScan Scanner	**TechMed3D**

19	3D Body Scanner	**Shape Analysis**
20	Elasizer Head Scanner	**Elasizer**
21	Portable 3D Body Scanner and Body Analyzer	**DIGIME**
22	SYMCAD III	**Telmat Industrie**
23	3D Instagraph	**Staramba**
24	Ditus MC	**Human Solutions**

4.2 3D scan processing

Two main companies have software to deduct 1D body dimensions (like stature, chest circumference, hip circumference) from 3D scans. These companies are SizeStream/TC^2 and Human Solutions. This software is generally supplied with their 3D scanners. However, other scanner manufacturers like 3DMD claim that they can also supply the software linked to their scanners, when desired. The software typically calculates over 100 body dimensions, some including assessed volumina. While manual measurements are specified in standards, this is not the case for computer derived body dimensions. ISO 20685 specifies the accuracy requirements for 1D scan derived body dimensions regarding 3D body scanning systems (http://www.iso.org/iso/catalogue_detail.htm?csnumber=54909). IEEE is currently working on new standards regarding 3D body processing. Director of this new initiative is Rudi Schubert (r.shubert@ieee.org).

Easy to use and free of charge software to visualize and process body scans is meshlab (http://meshlab.sourceforge.net/). Expensive and more advanced software is Polyworks (http://www.innovmetric.com/).

Specific software to link anthropometric databases to clothing design is made by Human Solutions: isize (https://portal.i-size.net/SizeWeb/pages/home.seam).

The main suppliers of software that allows for virtual design of garments on a 3D body are: Optitex (www.optitex.com), Gerber (www.gerbertechnology.com), Lectra (www.lectra.com) , Gemini (www.geminicad.com), DCsuite (http://www.physan.net/eng/DCsuite/product_qual.asp), Clo3D (www.clo3d.com), and Assyst (http://www.human-solutions.com/group/front_content.php?idcat=214&lang=2).

If a large database of 3D scans is available, a human model can be made based on a part of the scans. Using principle component analysis (PCA), the deviation from the model can be calculated for each individual. The first principal components are generally related to stature and body mass, but also

posture differences can be detected. As far as known, there is no software available that does this job; it depends on work of experts like Allan&Popovic in the USA, Shang Shu in Canada, Ter Haar in The Netherlands and Ballister in Spain.

Imorph is a project of DITF Denkendorf and Human Solutions. Experts from Human Solutions attached a morphology assessment to a 3D shape of a human. They use triangles and rectangles to classify bodies. This does not add any information, also 'expert' opinion is far from consistent. It is sad to see that this is still done, while Principle Component Analysis (PCA) is a completed automated technique to quantify body shapes.

5 Convertors and plug-ins

5.1 Description

If a certain garment fits you well, and you are in the market for a good fitting garment of another brand, a **convertor** may provide a good solution. Fig. 1 shows that sizes differ between brands. Fashionfitr (www.fashionfitr.com) is an example. It is necessary to have good conversion tables between brands in order to make a good transfer.

Very handy is the website www.kledingmaten.net that offers conversion tables for children and adult sizes for several countries.

The Amsterdam based company Myfashionsize (www.myfashionsize.com) offers companies to implement their sizing charts on the website so that the garment size recommendations is optimized.

In her Bachelor Thesis Noortje van Hooijdonk evaluated **plug-ins** in 74 retail companies that have a web shop. Plug-ins are tools that pop up during internet shopping for garments and provide a tool to determine the right size of the desired garment. The tools that were most commonly used were Virtusize https://www.virtusize.com/site/how-it-works, Myfashionsize http://myfashionsize.com/, Fitanalytics https://www.fitanalytics.com/, and Fitizzy https://www.fitizzy.com/. Table 2 shows a part of her inventory.

Table 2 – Inventory of tools used for size determination (Bachelor thesis Noortje van Hooijdonk – in Dutch).

				Broeken													
Nummer	Merk/ bedrijf	Sector	Land	Foto item	Foto op model	360 graden foto	Catwalk video	Maattabel	Info model en maat	Uitleg fit artikel	Video hoe je moet meten	Virtusize	myfashionsize.com	Fitanalytics	Fitizzy	3D body scan in winkel
1	Perfectly basics	Basics	Nederlands	Ja	Ja	Nee	Nee	Ja	Ja	Nee	Nee	Ja	Nee	Nee	Nee	Nee
2	By Bar amsterdam	Basics	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
3	Jeans centre	Denim	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
4	Nudie jeans	Denim	Scandinavisch	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee
5	Levis	Denim	Amerikaans	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
6	Denham	Denim	Nederlands	Ja	Ja	Nee	Nee	Nee	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
7	Piogg	Jassen	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
8	Rainfest	Jassen	Duits	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee
9	Airforst	Jassen	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee
10	Canada Goose	Jassen	Canadees	Ja	Ja	Nee	Nee	Ja	Ja	Ja	Nee	Nee	Nee	Ja	Nee	Nee
11	Goosecraft	Leer	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
12	Oakwood	Leer	Frans	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
13	Hunkemoller	Lingerie	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
14	Christine le duc	Lingerie	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
15	Livera	Lingerie	Nederlands	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
16	Lincherie	Lingerie	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Ja
17	de Bijenkorf	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
18	Nelly.com	Multi brand store	Scandinavisch	Ja	Ja	Nee	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee
19	Zalando	Multi brand store	Duits	Ja	Ja	Nee	Nee	Ja	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee
20	Asos	Multi brand store	Engels	Ja	Ja	Nee	Ja	Ja	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee
21	Wehkamp	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Ja	Nee	Nee
22	Fashionize.nl	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Ja	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee
23	Modemusthaves.com	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Nee	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee
24	Bever	Outdoor	Nederlands	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
25	The North Face	Outdoor	Scandinavisch	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Ja	Nee	Nee
26	Fjall raven	Outdoor	Scandinavisch	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
27	Miss etam	Plus size	Nederlands	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Ja	Nee	Nee	Nee
28	X-two	Plus size	Nederlands	Ja	Ja	Nee	Nee	Ja	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee
29	Bellyfashion.nl	Positie kleding	Nederlands	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee
30	Belly button	Positie kleding	Duits	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
31	Sam Friday	Sport	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee
32	Nike	Sport	Amerikaans	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
33	Asics	Sport	Japan	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
34	Under Amour	Sport	Amerikaans	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
35	We are labels.com	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Ja	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee
36	Bronprix	Multi brand store	Duits	Ja	Ja	Nee	Ja	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
37	Pure brands	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Nee	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
38	Locals united	Multi brand store	Nederlands	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
39	Hema	Lifestyle brand	Nederlands	Ja	Nee	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee
40	H&M	Lifestyle brand	Scandinavisch	Ja	Ja	Nee	Nee	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Nee

5.2 Evaluation of FashionFitr and Fitanalytics

5.2.1 Introduction

As part of the RAAK MKB project 'Fitting garment online' we investigated the accuracy of online fitting tools. The goal of these fitting tools is to help you determine the right size, so the number of sizes to be send to the customer or the number of returns will be small.

Wehkamp uses FitAnalytics to help you determine the best fitting size. It predicts the size you need based on previous purchases by other customers who filled in comparable body dimensions as the customer, and did not return that item. It than gives you a percentage of how sure it is you will fit that

particular size. Koopman Mode uses the Fashion Fitr tool, which also predicts the best fitting size. You can choose between

1 Comparing the garment with the size of garment you currently own. In this case you need to fill in the brand and size of that garment;

2 Using your body measures to calculate the best fitting size. In this case, you need to fill in your waist circumference, hip circumference and inseam length.

When the Fashion Fitr tool gives you the recommended size, you can also see if it will be perfect or slightly large or too small on the hips or waist. You can than choose for a size smaller or larger.

5.2.2. Methods

We have ordered the full size ranges of two different women's pants. The first is a striped tailored pants from Scotch and Soda (art. Nr 143541) which was ordered and delivered in the European sizes XS(34), S (36), M (38), L (40) and XL (42). The second one is pair of dotted slim fit pants from Expresso (art 181Abri 380 navy) which came in the sizes 34, 36, 38, 40, 42, 44 and 46.

The subjects were asked to pretend like they were ordering the pants for real. They visited the websites www.wehkamp.nl and www.koopmanmode.nl to order both pants at both websites.

First, they were asked which size or sizes they would usually order. The subjects were allowed to have a look at previous reviews, product details, payment and return regulations etc. but could not use the online plugin for size determination. This accounted for both websites, for both pants. The selected size or sizes were registered by the test leader.

Second, the subjects were asked to proceed with the sizing tools on the Wehkamp and Koopman Mode websites. The predicted sizes of both pants at both websites were noted by the test leader, as were age, weight, length, waist, hip and inseam length.

Third, the subjects were asked to fill in a questionnaire about FitAnalytics and Fashion Fitr, if they trust the tool, if they think the tool has an added value etc. Halfway the questionnaire, the subjects were asked to try on the pants in the recommended size. After the fit of the recommended size, they could try on the size they would have ordered without the help of the plug in. The test leader noted the best fitting size of both pants. After the fit session, the subjects were asked to continue with the questionnaire. The second part of the questionnaire was developed to discover how the opinion about the tools was changed depending on if it predicted the right size or not.

5.2.3 Limitations

During the testing period, the Fashion Fitr tool did not work at all for the Maison Scotch pants. This means the tool could only be tested for the Expresso trousers. The FitAnalytics tool on the Wehkamp website worked on and off. Sometimes it worked for weeks in a row, later on it suddenly stopped working. This had nothing to do with the items going on sale, or even being sold out. This means we had hard times testing the tools properly with enough subjects. In the end, we had a total of 26 subjects.

Two of them could only test the FitAnalytics tool, due to technical issues for the Expresso trousers on the Koopman website as well.

For some of the subjects, the chosen pants were not their taste. Some didn't like the fit, so it was harder to determine if the size was right or not. We simply asked them the question, if they were made to wear the pants for one day, which size would you choose? If the size is too big, the pants will fall down. If it is too small, it won't be comfortable to wear. A number of subjects were too big to fit in the sample range, so they didn't fit any of the sizes.

There were also limitations in the use of FitAnalytics. One step to determine the right size is to compare the chosen item with a piece of garment you currently own and wear. However, some of the subject didn't know the brand, style and/or size of the garment they currently wear. In a number of occasions, the brand the subjects wore, were not in the list. A considerable limitation is that this step cannot be skipped. This led to the fact that some subjects just made up something, which of course influences the results.

5.2.4 Results

Statistical analysis of the data is not warranted due to the large number of missing data. Therefore, we choose to describe our observations in a narrative manner.

The majority of the subjects order multiple sizes when they order trousers online. Eight subjects claimed to never order multiple sizes. 16 Subjects have used an online sizing tool before. There appears to be no difference for the subjects between the tools when we asked them if the tools were user friendly, easy to find and clear in use. However, FitAnalytics scores higher on the level of trust: 64/100 compared to 38/100 for FashionFitr. Out of the 26 subjects, 80% of them would follow the size advice given by FitAnalytics. For FashionFitr this is only 40%, which indicates that the level of trust is rather low for FashionFitr. The pants in the size of FitAnalytics scored a 59/100 on average, where FashionFitr scored 31/100.

So, the big question is: do the size plugins predict the right size? And, do they decrease the number of returns? In this research, 11 of the 26 subjects would order 2 sizes of the pants we made them buy, based on their own insight and without any advice of the tools.

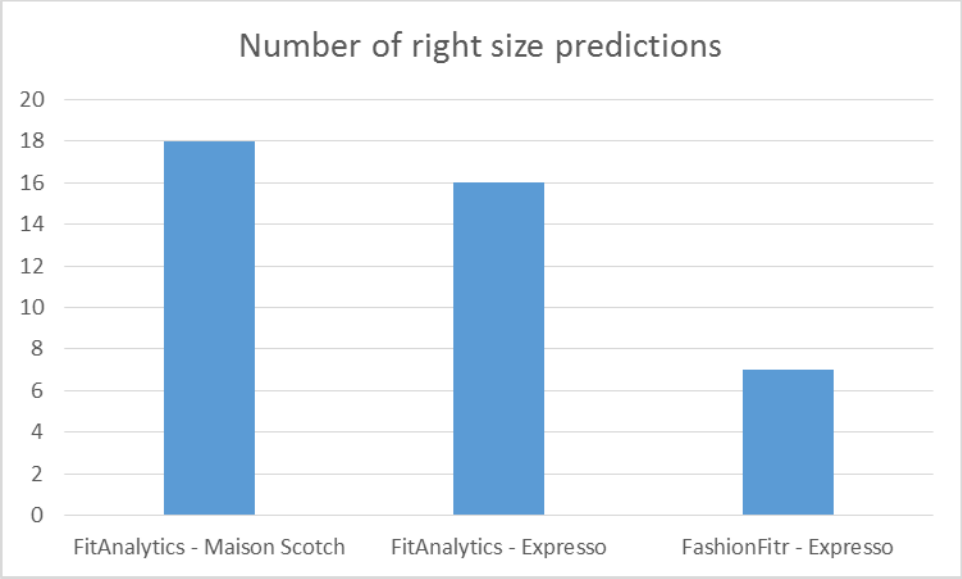

Fig 12. the number of right size predictions, based on the online size advice tools FashionFitr and FitAnalytics (total N = 26)

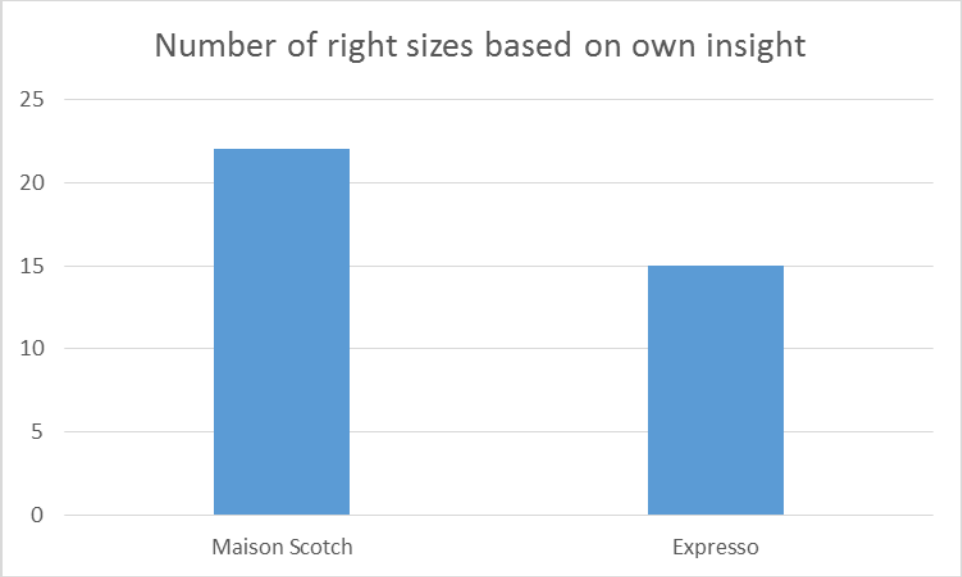

Fig 13. the number of right size predictions, based on own insight (total N = 26). Please take into account that subjects could order multiple sizes to increase changes of receiving the right size, this occurred in 11 cases.

As you can see in figure 12, FitAnalytics is in this research better at predicting sizes than FashionFitr. We had the impression that a considerable prediction error was present in the FashionFitr plugin. We took measurements during several days, so the results could not be ascribed to a single bad day.

Overall, people are better at guessing and predicting their size than the plugins are. But take note of the fact that people could order multiple sizes if they wanted to, which happened in 11 cases. So their

changes are bigger of receiving the right size. But that also means that at least 1 item has to be returned. If we add those double items to the wrong sizes, a total of 12 Maison Scotch pants had to be returned. For the Expresso pants, 21 items had to be returned (see Fig 14)

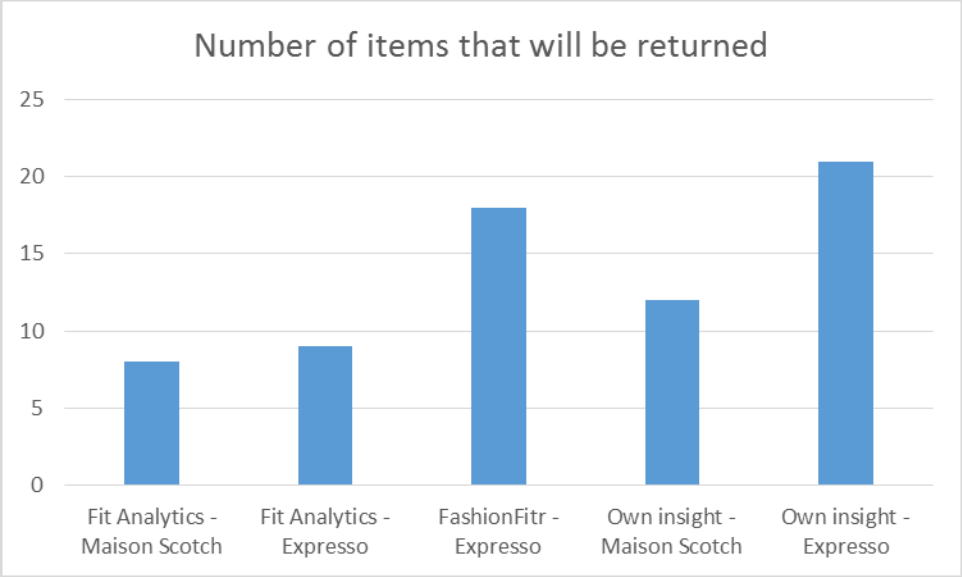

Fig 14. the total number of items that will be returned. For the online size prediction tools, this means they predicted the wrong size. For the subjects' self reported values (own insight), this is a sum of wrong size prediction based on own insight and items that have to be returned because of multiple size order.

5.2.5 Conclusion

FitAnalytics will reduce the number of returns IF people trust the tool and only order the recommended size.

6 3D printing and 3D knitting

6.1 3D printing

The possibilities of 3D printing are rapidly expanding. The costs decrease at a rapid rate. 3D garment printing is rare. A good overview is given by https://www.sculpteo.com/blog/2016/01/27/making-wearable-3d-printed-clothes/. Most garments have the form of chainmail. A pioneer in this area is electroloom: https://3dprintingindustry.com/news/electroloom-3d-printing-the-dawn-of-a-new-age-of-clothing-49167/.

Assemble3D (www.assemble3D.com) investigates different opportunities to 3D print body related products.

6.2 3D knitting

3D knitting of garments depend on the quality of knitting machines. Two main players are on the market: Stoll (www.stoll.com) and Shimaseiki http://www.shimaseiki.com/product/knit/. Both manufacturers are exploring the capabilities of 3D knitting. In the Netherlands, knitwarelab

(www.knitwarelab.nl) has access to a Stoll machine and Rosanna van der Meer (www.rosannavandermeer.com) to a Shimaseiki system.

Open knit (http://openknit.org/) is an initiative to make a simple knitting machine that allows for experimenting with new designs, including 3D.

7 Consultancy

7.1 Fit consultancy

Body2garment is specialized in recommendations regarding fitting of garments (www.Body2garment.com). Alvanon (www.alvanon.com) is also specialized in garment fit as well as sizingscience (www.sizingscience.com).

7.2 Styling consultancy

In a regular retail shop, personnel is available to give expert advice on the fit and appearance of apparel specific for the individual customer. However, when surfing the internet, those experts are generally not available. Some companies specialized to give clothing advice over the internet.

Examples are:

Wallis (http://www.wallis.co.uk/en/wluk/category/your-style-adviser-2567573/home?geoip=noredirect) that asks some questions on colour, body shape and style on which it generates an advice.

The dressing room (http://www.the-dressingroom.com/style-assistance) invites customers to make an appointment to meet an expert.

http://curvetips.com is another style advisor.

8 Other

Some companies offer a combination of different technologies. The company Truefit for instance (www.truefit.com) offers four possibilities: 1) a confidence engine with information on fitting for the client without having to enter information, 2) a discovery engine in which the client can enter info on his body dimensions and preferences, 3) Omni, a tool in which options 1 and 2 are implemented for the supplier and 4) True Insight with statistics about sales. The website does not contain much information , they claim that they serve a large number of retailers.

Suit supply offers four options in tailoring services (http://eu.suitsupply.com/en/content-page-tailoring-in-store-tailor.html): (1) in-store tailor that offers on the spot alterations of a newly bought suit, (2) on demand fitting & styling by a specialist in the Amsterdam shop, (3) design your own in which you can combine different items for suits and shirts and (4) made to measure in which your body dimensions are determined by a tailor that makes a suit and shirt fit to your body.

https://euveka.com/en makes real live manikins for clothing design that can be scaled to body dimension.

Bodime (http://bodi.me/) offers 3 options for body size determination: manual measurements (see par. 2.3), smart questions (see 2.2) and 3D scanning (see chapter 4). The site however does not seem stable and crashed several times.

Edolly (www.edolly.com) offers access to a 3D scanner so that a personal account with body dimensions can be made. Clothing can be virtually fitted using this information.

Special attention should be paid to the company Magic Leap (www.magicleap.com) in Florida, US. They have attracted 500 M$ funding from Google and 700 M$ funding from Alibaba to generate new experiences in mixed reality. This is a massive effort with funding exceeding four times the yearly budget of the Dutch government for NWO R&D funding. Although no specific information is available on the website, leading anthropometric and biomechanics experts are working on the topic which may include new methods for clothing sales over the internet.

9 Recommendations

9.1 Retailers with a web shop

For retailers with a web shop it is recommended to follow the steps below:

1 Evaluate your current method in your web shop that you use for determining the garment size

2 If the user has to choose the clothing size (S, M, L or confection sizes), consider to add some questions on body dimensions (see chapter 2) and investigate how the body dimensions are related to clothing size so that you can give a recommendation for better sizing. Also consider to contact a company providing convertors or plug-ins (chapter 5) for improved fitting.

3 Since most customers use hybrid shopping (using a web shop ánd visit to a physical store) consider using tools in the shop to determine body dimensions of the customer and translate this to garment size so that the customer can quickly go to the right spot in the shop (e.g. using a tablet – chapter 3 or when space and budget allows a 3D body scanner – chapter 4).

9.2 Education

The future generation should be aware of the challenges that fashion stores face in selling their goods. The gradual shift from pure physical outlets to hybrid shopping as well has societal impact that are well described in a recent book (Jongen, 2018). More technical details, like on 3D scanning can be found in another book (H. A. M. Daanen & Psikuta, 2017).

The information in this report is unrestricted and may be used for teaching purposes.

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