Interactive Product Visualization for an In-Store Sales Support System for the Clothing Retail

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Abstract. The development of an in-store sales support system that focuses on the "virtual try-on" of clothing is the aim of the research project "IntExMa". Based on sophisticated virtual reality technology, the interactive system provides visualization of made-to-measure shirts in combination with digital customer counterparts. The system is intended for seamless integration into existing processes at the point-of-sale and for the support of the collaborative consultation process between salesperson and customer. This paper describes the various system parts stemming from different research disciplines and their integration under the goal of high usability in an everyday setting.

Keywords: Sales process support, usability, virtual try-on, physically-based simulation, product visualization.

1 Introduction

Computer-supported visualization of clothing has been an important topic in the textile business for many years. One recurring idea in this respect has been the support of clothing sales by a virtual try-on of garments: A digital representation of a human being (avatar) is dressed in digitally represented clothing with the aim to provide a statement of fit and optical appearance of the respective garments in reality.

Rather different technical approaches have been taken to implement this promising concept. A typical representative of the technically more lightweight solutions is, for example, My Virtual Model Inc. [1]. This service offers avatars with limited customization options and does not consider individual body measurements. It can be classified as "pseudo-3D", as the dressed avatar can be viewed from four different sides. Some well-known apparel distributors (Lands' End®, Hennes & Mauritz®, Adidas® etc.) employ the system on their websites, though it can only give a rather vague impression of the clothing's fit and optical appearance for an individual customer.

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A major advancement in recent years was the realistic physical simulation of clothing and the according three-dimensional visualization on highly individual digital humans. The representative research project Virtual Try-On [2] was able to demonstrate a complete process chain: automated measuring of the customer via body scanning, generation of individual avatars, realistic simulation of correct fit, and authentic visualization of textile characteristics and drapery of the clothing.

High-end approaches like this suffer from limitations concerning the required processing time and the continuous automation between the different steps. This conflicts with the requirements of an interactive system and complicates the practicable integration into existing sales processes. At the moment, solutions for a high-end "virtual try-on" are a topic primarily for CAD applications in the textile sector, where garment designers are enabled to create virtual prototypes.

In this paper, intermediate results of the research project "IntExMa (Interactive Expert System for Made-to-measure Clothing)" are presented, aiming at the development of an effective "virtual try-on" system for a sales support that is point-of-sale compatible. The basic concept is to provide added value by supporting in-store, "real world" sales processes with e-commerce technology ("virtual shopping"). Here, we especially look at shops of small- and medium-sized enterprises that provide specialist products and services. The target setting is characterized by the interplay between customers and sales staff, where the intended system provides information, visualizes product data, and supports a well-founded buying decision. Sales assistants shall not be replaced, but shall rather be supported naturally and unobtrusively in their interaction with the customers.

The aim to enrich the shopping process at the point-of-sale with information technology does not intend to overload the shops with sophisticated and expensive state-of-the-art equipment, especially when it comes to hardware. On the contrary, it is intended to keep the solution affordable, space-saving, and easy to integrate in existing store environments and processes.

The particular sales context addressed in this work is made-to-measure shirts. Though provided with examples of the available array of fabrics and other product components, e.g. collars, and some made-up shirts, customers are usually not able to preview the shirt with all their specifications. Virtual product representations can enable customers to get a clearer understanding of their selected combination as a complete shirt. Furthermore, information technology has the potential to support the selection process and to improve access to a large range of design alternatives.

From the user's perspective, the main system components are a large-sized three-dimensional product visualization and separate user interfaces for customers and sales staff (see Fig. 1). During consultation, the sales assistant enters the customers' body measures into the system. From that data a three-dimensional figure is automatically generated and dressed in the desired made-to-measure shirt, following the metaphor of a "virtual mirror". As the shirt representations are generated individually from real sewing patterns, their drape is simulated with according physical parameters, and the texturing and lighting is optimized for a high degree of realism. The system provides a proper evaluation of fit and optical appearance of the later product for the individual customer. The possibility to easily compare different shirt configurations further supports the buying decision.

The main contribution of the reported work lies in the exemplary realization of a system that is able to visualize and make accessible a comprehensive data space of product and customer data (individual made-to-measure shirts and virtual figurines) in an effective, integrated, and easy-to-use way.

We demonstrate a usability-driven implementation of a complex system concept. This concept implies the demand for an efficient system that reacts to customer input in a responsive way. Thus, state-of-the-art technology from different research disciplines is made accessible with rather basic user interface components to provide intuitive functionality that is easy to use by non-specialists in an everyday setting.

Fig. 1. IntExMa prototype: customized interaction device (middle) and 3D product visualization with GUI on top (right)

2 Method

In order to ensure high usability and user acceptance for the system, it was decided to adopt a user-centered design process according to ISO 13407 [3]. This implies the steps: i) context of use analysis, ii) requirements specification, iii) production of design solutions, iv) evaluation of design results with the two end-user groups, salespersons and customers, and (v) feedback into the next cycle. Repeatedly, different user interface alternatives are considered during the design phases, implemented as rapid prototypes, and tested in the project labs. The most promising alternatives find their way into the superordinated system.

Test participants were always matched to the demographic profile of shirt shop customers and sales staff. The evaluation phase of the first cycle took place with real customers and salespersons in the real made-to-measure tailor shop of one of the project partners in Hamburg, Germany.

A user-centered design process is naturally very adequate for a system's front-end or its user interface, respectively. In parallel, the advancement of the different back-end software components has to be aligned with the test cycles. The requirements for the avatar generation, for the 3D-enabled garments including pre-positioning and physical simulation, and for the realistic visualization have been quite stable from the start and were hardly influenced by user test results. Nevertheless, in order to have fully functional versions ready to be deployed for the different prototype releases and the user tests, the work plan was partitioned into incremental packages.

During the project, two cycles are conducted including a subsequent finalization phase for incorporation of the final user test results.

3 Design and Implementation

3.1 Avatar Generation

One basic requirement for the implementation of the "virtual mirror" metaphor and an effective checking of fit and appearance of the clothing, is the support of realistic and individual digital humans. Their measurements and proportions must be optimized for a convincing product illustration result, in combination with the simulation component.

The area of digital humans has been the subject of research and development for approximately twenty years. In [4], Magnenat-Thalmann and Thalmann provide a comprehensive overview of the plenitude of methods. Many techniques can not be completely automated, while many others require complex technical equipment. In contrast, this project's approach is the use of simplistic technique with a minimum number of measures and without the need for body scanners. For the context at hand, the method "parametric deformation" was chosen: Provided with sparse input data it can deliver impressive results and does not call for special equipment in the shop.

Parametric deformation is based on the linear transformation of vectors. In our case, a complete 3D human figure consisting of a polygon mesh is required as a base model. Starting from this basis, all deformations need to be created only by relocating existing vertices - the so-called morph targets. For a specific deformation one or several relocations are applied concurrently, each weighted with a specific value.

As the resulting avatars must comply with the given body measurements, we apply a measuring algorithm. Based on the polygon mesh it calculates the sum of distances between a predefined number of vertices in a specified order. This concept covers girth and length measures, likewise.

The deformation process is performed in discrete steps - morph actions alternate with the measuring of the according measuring section. This sequence stops as soon as the specified dimension is achieved or when it satisfies a predefined tolerance value, respectively. The initial deformation value is predicted based on the assumption of a linear dependency between two test measurements that are initially calculated.

Morph targets may also cover aspects of the human body appearance like age and gender that go beyond body measurements. Here, a fuzzy-style curve can be defined as input filter in order to achieve nonlinear mappings. This solution also supports color per vertex as well as texture mapping. Several tools have been developed for the preparation of a “generation” of avatars – base avatar plus morph targets – e.g. for measuring the section definition, the generation of real-world to model scaling factors, and the graphical analysis of the target quality.

The quality of the results highly depends on the quality and quantity of the input data. The more detailed the base avatar is and the more morph targets and measuring sections (and measurements) are provided, the more precise the reproduction of the real person will be. Currently, we model the avatars with the help of standard software for digital human modeling and we are using 10 morph targets.

3.2 3D Enabled Garments

Apart from the realistic generation of the avatar, another step is the generation of realistic garments. To perform this step, initial patterns with the following properties are required: i) the patterns must be generated to be made-to-measure; ii) according to the components selected by the customer the corresponding patterns have to be generated, e.g. specific collar, cuff, pocket etc.; iii) the generation of the patterns have to take place automatically, i.e. without human interaction. In addition, the interface to the 3D simulation has to be supplied with information for the 3D representation and simulation, e.g. seam information, orientation in space, information for the prepositioning, information on buttons, pleats, darts, logos, and a few more. This information is also important for a realistic 3D representation.

To generate such patterns and information it is necessary to have the underlying garment constructions. Due to requirement ii), one sees easily that there are many possibilities of combinations. Requirement iii) includes, that there must be a description of the garment construction, which can be handled in an easy way and which is flexible concerning the variants. The descriptions of the pattern constructions are stored in XML format. To describe the constructions in XML, an XML schema definition was set up that defines construction steps. To ensure that all combinations can be generated, the separate steps are designed in a way that they can be parameterized by measure data and fitting descriptors. Each step may or may not be executed according to the selected combination of components.

The XML schema also covers the elements for the 3D simulation, especially seam information, button information, information on texture, and material properties which are necessary for a realistic 3D representation. To define this information in the construction, they are again built as steps with the advantages aforementioned. Thus, this information can depend on the fitting. For instance, it is possible that there is the same pattern, but with different seam information.

Different pattern constructions can be stored in separate files. This keeps the descriptions of the constructions easy to handle to some extent. A method has been developed for the selection of the files. This selection is also defined in XML. It may happen that the construction in one file depends on a different construction in another file. In this case, the execution sequence of the constructions is important. The pattern generator recognizes these dependencies.

The whole pattern generation process happens as follows. The fitting parameters are passed from the user interface to the pattern generator. In the first step the corresponding files are chosen. Usually, there will be a set of files for one garment. Due to the possible dependencies described in the previous paragraph, it is then necessary to sort the files in the right sequence. For this, a graph representation of the sequence is used. In the next step, the constructions are executed, which results in a set of patterns with all the descriptions that are required for the simulation. In the last step, all the information is put together in one XML document that is passed to the 3D simulation.

3.3 Pre-positioning and Physical Simulation

The simulation of the real-world process of dressing can be very complex, e.g. the simulation of a person that tries to get in a sweater would involve complex movements of the arms. However, there is a much easier way to dress virtual humans, which was proposed by Volino and Magnenat-Thalmann [5]. There, the single cloth patterns are positioned manually around a virtual human body. But time-critical applications like the proposed interactive product visualization require automated and faster mechanisms. In this context, a pre-positioning by user interaction must be replaced by an automatic pre-positioning.

Therefore, a novel approach was proposed by Fuhrmann et al. [6], where the virtual cloth patterns are positioned automatically on bounding surfaces that enclose the body segments, e.g. torso, arms and legs. The resulting pattern positions serve as initial positions in the following physically-based sewing process. It is also possible to pre-position several garments simultaneously by computing a series of bounding surfaces lying upon each other. Also, pockets of a shirt can be handled as patterns and pre-positioned over a shirt. Accessories like buttons are also processed during the pre-positioning.

We use a particle system for the realistic physically-based simulation of the triangulated garment patterns. The movement of each particle is controlled by Newton's laws of motion. Internal cloth forces can be very large due to the fact that cloth strongly resists against stretch. The standard approach to cope with this is to use an implicit time integration method [7]. These methods allow large time steps for the simulation but unfortunately require considerable computational efforts per time step. We follow another approach of Fuhrmann et al. [8], which avoids large forces and can be computed very efficiently. The key idea is to replace internal forces by geometric constraints, which can be parameterized for different cloth behavior. Besides efficiency this method has the advantage that it is extremely stable, and is therefore ideal for interactive systems. This is particularly useful if the user of the system is not a simulation expert but a salesperson.

During the simulation, the patterns are sewn together along their seaming lines. After sewing, gravity is activated and the garment is put into its final shape. The simulation is stopped when the particles reach a stable state.

The physically-based simulation also has to handle self-collisions and collisions between the human body and the cloth. Numerous methods have been proposed in

Fig. 2. An avatar dressed with a shirt. The close-ups show details like the collar, the 3D buttons and seam threads. The image in the lower right was rendered without the avatar and self-shadowing to visualize the cloth thickness and the seam allowance of the cuff.

recent years, cf. [9] for an overview. Our system solves the problem by testing only particles against the surface of the body and each other. This approach saves a lot of computations compared to a full triangle-triangle intersection test. Distances between particles and the human body are rapidly computed with a signed distance field [5].

3.4 Realistic Visualization

The simulated garments and the virtual human are finally visualized. In order to create realistic images, a photo of a real environment is used for lighting the virtual scene. One can think of specific light situations like a sunny landscape or even the real shop in which the customer is standing. By using several 360° photos of the environment the complete dynamic range of real light can be captured. This results in a high-dynamic-range (HDR) environment map, which is used to light the virtual scene.

Besides correct lighting, shadows and self-shadowing must be considered to create realistic images. We employ structured importance sampling [10] to transform the HDR-image into a set of directional light sources. For the rendering of shadows cast by directional light sources we use numerous shadow maps [11]. Although shadow maps work in image space and are often prone to aliasing artifacts, they are a good choice, since the effect of aliasing decreases by increasing the number of lights.

Further important aspects of realistic visualization include details like the seam allowances, seam threads and imprints. We create additional geometry for the seam allowances automatically from the input data, where the width of each seam allowance is specified. In contrast to a thickening of the cloth, which can be done by simply extruding the geometry, the seam allowances are modeled as a stripe of geometry with constant width. This stripe is then attached to the border of the patterns and folded around (see Fig. 2).

The seam threads and imprints are visualized with additional textures. These textures are partially transparent and rendered after the original pattern texture. For the seam threads, extra sets of texture coordinates are computed in order to be able to visualize highly detailed seam threads.

Fig. 3. PDA (3D interaction mask) and an interaction device with knob and buttons

3.5 User Interfaces

The basic interaction concept of the IntExMa prototype is oriented at a collective system usage by customer and salesperson. While the latter has access to the entire functionality of the system, only selected functions are offered to the customers. This aspect results from interim usability tests, where only the shop personnel interacted with the system in the sense of maximized customer service and decreased complexity for the customer. However, the great majority of the customer test group members asked for independent access to at least some of the system's functions.

As a consequence, two different user interfaces are offered: a PDA for the sales staff and a special interaction device for the customers. The interaction device consists of only two buttons and a rotating knob (see Fig. 1 and 3). These two specific interaction means were chosen based on a sustained program of research conducted during “IntExMa” and a previous project [12].

Via the PDA, the salesperson has access to the electronic product catalog with capacious ordering functions, the customer database, and the 3D interaction functionality. Concerning the latter, the PDA works like a remote control. If the actual shirt configuration is altered on the PDA, the changes are directly transferred to the ‘virtual try-on’ and a new simulation is initiated. In case of exchanging the cloth, only the texture is exchanged to save the simulation time. As soon as the customer's body measurements are entered, the according avatar is generated and directly displayed and dressed. Normally, the virtual figures are only shown completely vested, but alternatively the pre-positioning and the simulation (see above) can be visualized. Furthermore, the salesperson can turn the avatar around its vertical body axis and zoom in to details of the shirt. A bar-code scanner is integrated into the PDA. It allows to scan real products in the shop resulting in direct alteration of the shirt configuration in the PDA and the 3D scene.

Concerning the user interface design of the PDA, we tried to adopt existing expertise in the form of design guidelines. Results of an accordant analysis indicated that handheld design is only sparsely covered yet, especially when it comes to business process support. Our current PDA design is based on the analysis, interpretation and amendment of established guidelines for desktop user interfaces, e.g. ISO 9241 and some of the rare mobile design guides, interpreted for the present context of use. The results of this work, a rather complete set of principles, exemplary rules and according concrete examples have led to a separate publication [13].

The interaction device hardware was custom-designed, as no commercially available device could be found, that provides the desired form factor, simplicity and robustness of construction. The associated 2D graphical user interface (GUI) is overlaid on top of the 3D product visualization (see Fig. 1). The aim was to exploit the available display area as widely as possible without covering the relevant 3D content.

With the green confirmation button the user can invoke the GUI and the product catalog, navigate to different levels of its hierarchical structure, and choose the desired shirt components, which are again directly illustrated in the “virtual try-on”. The currently configured product detail is at the same time automatically zoomed in within the 3D scene. The red abort button allows going backwards in the navigation path and, having reached the top level, allows fading out the GUI. Browsing the different entries inside a menu level is achieved with the rotary knob. With its help, the avatar can also be rotated, presumed that the GUI is “closed” (faded out). Both, PDA and interaction device, operate on the same data and can be used concurrently.

4 Results and Conclusion

The results of this work can be split up into technical and usability-related findings. From the technical point of view, the project has successfully achieved to integrate sophisticated state-of-the-art technology from different research disciplines (virtual reality, textile engineering, physics, and mathematics). The result is a rather complete and self-contained system consequently oriented at the demands of the point-of-sale. Room for improvement can nevertheless be identified: reduce overall computing time for improved interactivity, allow further customization of avatars for better individualization (though in the limits of available customer data), and reduce required manual effort for digital content production.

Concerning usability, we demonstrate an example how the context of use of a particular area, sales process support at the point-of-sale, shapes a technically complex system concept. The user testing conducted so far indicates the promising potential of the employed user interface concepts: Though being rather “unspectacular”, they successfully support our goal, to provide intuitive, effective and easy to use information access in an everyday setting. Also, the distribution of interaction possibilities between customer and sale staff is appreciated. It balances the service demands and the "play instinct" of the customers. Also, the customers like the idea of being supported by the salespersons in this way. The latter esteem the system's abilities to depict complex information, which enhances their customer consultation.

Our approach to a "virtual try-on" for made-to-measure clothing in the shop was rated to provide added-value to made-to-measure shirt shopping - by customers, sales staff and shop owners. Further detailed findings for the current prototype will result from the scheduled next evaluation phase.

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References

1. My Virtual Model Inc, last retrieved 15/02/07 http://www.mvm.com/
2. Virtual Try-On, (last retrieved 15/02/07), http://www.human-solutions.com/virtualtryon/index.shtml
3. ISO 13407, Human-centred design processes for interactive systems (1999)
4. Magnenat-Thalmann, N., Thalmann, D.: Handbook of Virtual Humans. John Wiley and Sons Ltd, New York (2004)
5. Volino, P., Magnenat-Thalmann, N.: Developing simulation techniques for an interactive clothing system. In: Proceedings of Virtual Systems and MultiMedia '97, pp. 109–118 (1997)
6. Fuhrmann, A., Sobotka, G., Gross, C.: Distance fields for rapid collision detection in physically based modeling. In: Proceedings of GraphiCon 2003 (2003)
7. Baraff, D., Witkin, A.: Large steps in cloth simulation. In: Cohen, M. (ed.) SIGGRAPH 98 Conference Proceedings, Annual Conference Series, Orlando, FL, USA. ACM SIGGRAPH, pp. 43–54 (1998)
8. Fuhrmann, A., Gross, C., Luckas, V.: Interactive animation of cloth including self collision detection. Journal of WSCG 11(1), 141–148 (2003)
9. Teschner, M., Kimmerle, S., Heidelberger, B., Zachmann, G., Raghupathi, L., Fuhrmann, A., Cani, M.-P., Faure, F., Magnenat-Thalmann, N., Strasser, W., Volino, P.: Collision Detection for Deformable Objects. State of the Art Report, Eurographics EG'04, August 2004 (2004)
10. Agarwal, S., Ramamoorthi, R., Belongie, S., Jensen, H.: Structured importance sampling of environment maps. In Transactions on Graphics 22, 605–612 (2003)
11. Williams, L.: Casting curved shadows on curved surfaces. In: Computer Graphics (SIGGRAPH 78 Proceedings), pp. 270–274 (1978)
12. Blum, R., Häberling, S., Khakzar, K., Westerman, St.: User Interfaces for an In-store Sales Process Supporting System. In: Proceedings of CIS^{2}E 06, International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (to appear)
13. Blum, R., Khakzar, K.: Design Guidelines for PDA User Interfaces in the Context of Retail Sales Support. In: Proceedings of HCII, 12th International Conference on Human-Computer Interaction (to appear, 2007)