Compositing Photographs with Virtual Clothes for Design

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Abstract: *This paper presents a computer system for garment designers to realistically augment photographs of a person with virtual garment designs. We show that the accumulation of existing garment modelling and computer graphics techniques can be used to produce realistic images of clothes in the context of a real scene. Effects of natural light interactions and fabric properties are taken into consideration. The system consists of a 3D scanner, a garment CAD extension, a garment simulation interface and a natural global illumination system. We describe how the components of the system are integrated and discuss a collaboration with a fashion designer who worked with the system.*

Key words: *Cloth Modelling, Global Illumination, Augmented Reality.*

INTRODUCTION

Recent block buster films that show computer graphics special effects, such as in "The Matrix Reloaded", "Pirates of the Caribbean", "Terminator III", etc., where real and naturally illuminated virtual images are merged smoothly often also require seamless realistic simulation of garments. In order to make the virtual garment behave like the real counterpart, it is important to predict the physical fabric drape properties. In such films scenes appear where real actors interact with virtual clothes. Typically such images require a lot of manual editing by skilled animators and a single image can require days to be finished. We assumed that such techniques with better computational performance and less manual editing would be of interest to a garment designer. Clothes appear differently in different environments. A client may approach a garment designer with a specific occasion in mind where she wants to wear the new design. For the designer it would then be beneficial to experiment with the new design in the target environment and to be able to show photo-realistic images of the customer wearing the new clothes at the specified location. Such a system will save time and cost for the process of clothing design.

Related Work

The prediction of the behaviour of cloth material has been of interest to the textile industry for a century and to the computer graphics community for more than 20 years. Kawabata et al [6] proposed the Kawabata Evaluation System (KES), a fabric measuring device to test a piece of cloth for several properties of interest to the textile industry. Breen et al [3] first demonstrated that the properties: resistance to stretching, shearing, and bending, from the KES are sufficient in a computer cloth simulation to approximate the fabric behaviour. They showed rendered images simulated with properties from the KES with photographs of the real cloth counterpart draped over a table. Real and virtual images showed similar drape behaviour. In [15] Vassilev described an adaptation of Breen's approach to map KES data to Provot's mass-spring model [10] for real time simulation.

In [4] Debevec described techniques to realistically insert virtual objects into photographs or video footage by exploiting light measurements from high dynamic range (HDR) images and a global illumination system, further described in the next section.

GARMENT SIMULATION AND ILLUMINATION SYSTEM

Our system requires the following input data:

- a 3D scan of the customer or a model with similar body size and shape,
- a garment description,
- photograph of the customer in the target environment,
- a light probe of the target environment,
- reflectance data of the fabric.

Customer Scan

To virtually try clothes on a customer's photograph it is necessary to first acquire the 3D body geometry of the customer. Typically this is achieved by means of 3D scanning technology which is widely available now. In our system we employ the TC^2 system which uses a technique called white light phase measurement profilometry in which images of a structured light grid projected onto the front and the back of the body are taken and from distortions of the light grid the body shape is acquired. The direct output of the scanner is a 3D point cloud. The body surface is reconstructed by TC^2 software and important body landmarks are extracted automatically.

Garment Assembly and Simulation

For the realistic simulation of garments a complex description of patterns, seaming lines, etc. is required. Attempts have been made to standardise the description of garments [2, 1] but they are vulnerable to misinterpretations and they do not provide sufficient information for virtual garment simulation. We have designed our own garment description in the form of a simple text format. It permits the description of the cutting patterns, fabric drape properties, seaming lines, garment accessories (such as buttons, cufflinks, etc.), extra layers for pockets etc., collars, textures and reflectance properties of the fabrics. More details about our garment description format can be found in [12]. A plugin for a commonly used graphics system was implemented to permit importing and editing garment designs and to read and write them in our file format. Our cloth simulation technique is based on the methods described by Vassilev et al. [14]. It uses a mass-spring particle system with a directional velocity modification method to compensate for super elasticity of the Hookean spring model. A very fast image based collision detection technique that harnesses interpolation and Z-buffer engines of the graphics acceleration hardware is employed. Our system generates mass-spring meshes from the garment description. Fabric property measurements from a KES are mapped onto the mass-spring system by using the mapping approximations described in [15]. In order to fit the garment around the body the individual panels are positioned automatically and joined along the specified seaming lines. This is achieved by exerting elastic forces on the vertices of the seaming lines during the joining process. Finally we apply gravity, as an external force to the particle system to drape the garment over the customers scan.

Merging Real and Virtual

In order to make the virtual garment appear on the customer's photograph, as if the customer were dressed in the garment, the photograph of the customer must be aligned with an image of the 3D scan of the customer. This can be achieved by extracting camera position and direction by using a camera calibration technique such as the one described by Zhang in [16] and by rendering the 3D scan and garment with the camera settings of the photograph. However, for camera calibration multiple photographs of a calibration pattern in the target scene are required which may not be available. Automatic alignment of the model with the image can also be found with image registration techniques. See Lester and Arridge [8] for a survey. If the pose of the customer in the image is significantly different to the pose of the customer's 3D scan, the scan has to be animated with the garment to approach the pose in the photograph as closely as possible. An automatic character animation system [9] combined with an image registration method is required to find the right pose automatically. In the system described we didn't concentrate on automatic model alignment. Instead, we superimposed the virtual model over the photograph and adjusted the virtual camera to visually match photograph and scan. See Figure 1.

Figure 1 3D scan superimposed on the photograph to approximate camera

Natural Global Illumination

The goal of *global illumination* is to approximate the behaviour of light interactions in a scene. *Global illumination* is of particular interest for the illumination of clothing because of complex light interreflections between fabrics eg, between torso and arms, or in the ridges, creases and folds of cloth. Such interreflections and soft shadow effects cannot be simulated with faster local illumination systems. *Radiosity* and *Monte Carlo path tracing* are the most commonly used approaches to find a solution to the *rendering equation* that takes such light interactions into account. RADIANCE [7] is one of the systems that approximates the real behaviour of light very well and is freely available in open source. It uses a Monte Carlo path tracer with an octree data structure and an irradiance caching strategy for improved speed. RADIANCE is mainly used for the illumination of architectural designs but is very flexible and can also be harnessed for the illumination of clothes. In [4] Debevec proposed to use RADIANCE with HDR panoramic photographs as light sources for global illumination in order to seamlessly insert virtual objects into real scenes. He coined this technique *Natural Illumination*. In Debevec's approach the panoramic HDR images are composed of photographs of a mirrored ball from the same view with different exposure settings (eg. varied shutter speed on the camera). We employ this technique for our system and exploit the panorama transformation and HDR composition features of HDRShop [13] to create a so called light probe of the target environment. A *light probe* contains the radiance measurements of the scene at a certain point, therefore, the *light probe* should be taken near where the customer is placed in the target photograph. An example *light probe* of our designer's office is depicted in Figure 2.

Figure 2 Light probe Radiance measurement of our designer's room the images depict the HDR light probe as 3 low dynamic range images at different f-stops.

After our real time garment simulation has converged to a stable state we convert the 3D mesh and the texture to a format that can be read by RADIANCE. The appropriate HDR panoramic image is loaded into RADIANCE and an image is rendered with the camera parameters acquired in the registration process. In order to render with indirect illumination, like a *light probe*, the number of diffuse bounces has to be greater than 0. In fact we set the number of diffuse bounces to two to account for fabric interreflections. Ambient sampling parameters are set relatively high to achieve good quality.

Reflectance Estimation

Owing to its microstructure the bidirectional reflectance distribution function (BRDF) of fabric can be very complex. We approximated the spatially varying fabric reflectance by taking photographs of a sample of the fabric in diffuse light. Colour and light calibration was achieved by inserting a MacBeth colour checker in the image with the fabric. The image is balanced afterwards so that the known values of the MacBeth chart best match those of the image in a least square sense. Since our sample was not large enough to cover the whole jacket we used a texture synthesis method briefly described below.

Masking the Rendering for Photo Composition

In order to subtract the garment from the background of the synthetic image it is necessary to create a mask image. The problem is that mannequin and garment interact and it would be difficult to generate a good mask manually. Instead we use a depth buffer approach. We create a depth buffer for the 3D scan and background without the jacket and another depth buffer image of scan with the simulated jacket. A simple filter function can then be used to generate a mask file. The filter function returns 1 if the depth value of the jacket is bigger than the depth value of mannequin and 0 otherwise. An example mask is depicted on the left in Figure 3. The right of Figure 3 depicts our rendered jacket subtracted from the background.

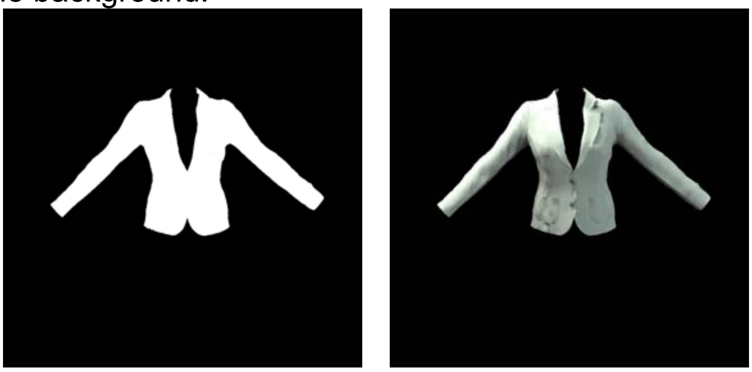

Figure 3 Left: Automatically generated mask image for merging the photograph with the illuminated geometry (Right)

Synthesis of Occluded Background

When merging images, usually the background where the new image is inserted is lost. Sometimes it is also required to remove parts of the background scene occluded by the real garment. For example parts of our client's real garments may not be sufficiently covered by the synthetic garment and therefore need to be replaced by the background expected in the image. Ideally an image of the background without the client is available, but if this is not the case, the background can be approximated by using so called texture synthesis techniques. Generally texture synthesis takes as input an area of the image that is similar to what should be regenerated. The area that should be recovered is marked and synthesized with a texture that most likely would have covered that area according to a probability distribution of the specified sample region. We employed a technique described by Harrison [5] for this.

EXPERIMENTS

We collaborated with a designer to test our system in a real world setting. As a simple garment we asked our designer to make a jacket. In order to verify our simulation our designer created the jacket not only in a CAD system for simulation but also made a real toile of the garment. The designer's client was scanned with the TC2 system and we took photographs of the client in the jacket for comparison. A *light probe* was taken in our designer's office.

RESULTS

Figure 4 on the left depicts a client in the real jacket toile and on the right an image of the client composited with a simulated garment. We note that owing to natural illumination the simulated garment fits realistically into the photograph. Since hands were chopped off the 3D scan they are not present in the composited image either. There are creases in the real jacket which don't appear in the simulation. In general the simulation appears much smoother. This may be for two reasons. Firstly, our garment simulation doesn't account for memory effects of the fabric, while secondly the resolution of the mass-spring mesh could be increased to generate more detailed creases. Both designer and client have found the system very useful and interesting. They commented on possible improvements mainly on the garment CAD and simulation interfaces.

Figure 4 Left client in the real jacket toile, right the illuminated and simulated jacket composited with a photograph of the client

FUTURE WORK

As mentioned earlier, registration between 3D scan and client photograph could be automated by using existing registration or calibration techniques. Automatic pose registration is particularly challenging and interesting. At the moment we don't take light interactions of the customer's garments in the photograph with the virtual garment into consideration. This would probably require reflectance and geometry measurements of the garments the client wears in the photograph and may be hard to acquire.

We are working on a technique to extract fabric drape properties directly from images to avoid expensive tests with a KES.

If naturally illuminated images from different views are required in real time a light mapping technique as described in [11] will be of particular interest since texture coordinate parameterisation is inherently given by the flat cloth panels, with which the garment simulation starts.

In order to assess the visual quality of our system we have prepared a user study on the web.

CONCLUSIONS

We have presented a system for designers to generate photo realistic images of a customer dressed in a garment that hasn't even left the design stage. In a collaboration with a designer we tested our system with a client. Both client and designer found our system interesting and useful. Many system improvements are possible as listed in the section on future work.

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