Garment Transfer for Quadruped Characters

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Abstract

Modeling clothing to characters is one of the most time-consuming tasks for artists in 3DCG animation production. Transferring existing clothing models is a simple and powerful solution to reduce labor. In this paper, we propose a method to generate a clothing model for various characters from a single template model. Our framework consists of three steps: scale measurement, clothing transformation, and texture preservation. By introducing a novel measurement of the scale deviation between two characters with different shapes and poses, our framework achieves pose-independent transfer of clothing even for quadrupeds (e.g., from human to horse). In addition to a plausible clothing transformation method based on the scale measurement, our method minimizes texture distortion resulting from large deformation. We demonstrate that our system is robust for a wide range of body shapes and poses, which is challenging for current state-of-the-art methods.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—

1. Introduction

In recent years, there has been an increasing interest in avatars and graphical characters owing to the rapid progress of graphics in films and games. In these films and games, characters are often expressed as Quadruped Characters with dresses in order to enhance familiality. These characters are made unique by modeling them with different body shapes. With a wide variety of body shapes, it becomes increasingly difficult to dress these characters since the designing, fitting, and texturing of the garments requires considerable manual effort. A number of methods have been proposed for mating these processes by generating clothing from a template, but their applications have mainly focused on dressing human body forms. There is a lack of methods for transferring clothing to characters with different poses and body shapes. In fact, transferring clothing for a graphical application poses new challenging problems that previous works have not addressed adequately. The main aspects that need to be considered when transferring a garment for graphics applications are as follows:

Scaling: A resulting model should be aware of relative scales between body parts. For example, while a horse has a larger torso than that of a human, its legs are thinner.

Fitting: Fitting of clothing needs to be preserved after transferring a template even if the target character has a different posture.

Texture: Texture coordinates must be defined in a template model. For a large deformation, texture is prone to unpleasant distortion.
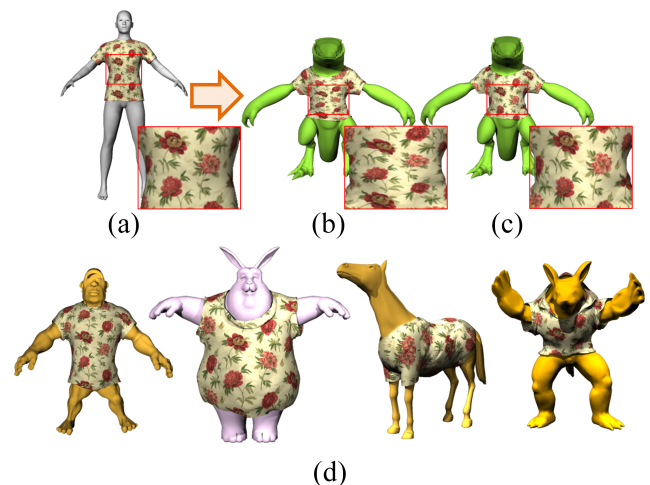
Figure 1: The result of Texture Preserving (constant weight) - (a) Source body and garment. (b) Cloth transformation without Texture Preservation. (c) With texture preservation. Our garment transfer system enables us to generate a clothing model for various characters preserving the fitting and its texture. (d) The results show that the transferred models preserve not only the fitting, but also the texture pattern.

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In this paper, we propose a method for transferring a clothing model to various characters from a single template model. A novel scale measurement between the source and target character inspired by human body measurement in the real world preserves the fitting of clothing. Our system also automatically modifies the texture space of a transferred clothing mesh so that the resulting model looks pleasant. Our main contributions are listed below:

- A novel concept of scaling enables evaluation of the relative scale deviation between characters (Section 3.1).
- Our generalized fitting algorithm is robust for any target poses and shape (Section 3.2).
- Our texture preservation algorithm significantly reduces the texture distortion (Section 3.3).

Our system makes it easier for users to model clothing by reusing existing models. It also allows users extend their creativity by dressing characters with a wide variety of shapes and poses. To the best of our knowledge, our system is the first garment transfer system for human as well as animal and fictional creature models.

2. Related Work

Recently, various transfer techniques have been proposed in order to simplify the creation of virtual 3D content. Sumner et al. [SP04] propose a deformation transfer method, which applies the deformation exhibited by a source triangle mesh onto a different target triangle mesh. As related to clothing model, Cordier et al. [CSMT03] propose the system which allows virtual try-on of garments on the Web according to shoppers' body measurements. However it cannot be applied to characters with a wide variety of shapes and postures because their method largely depends on the human model of database. Brouet et al. [BSBC12] present a fully automatic method for design-preserving transfer of garments between human characters. Their output have a low distortion mapping to a set of 2D patterns, enabling texture mapping and actual manufacturing. Unfortunately, their approaches assume that the characters are posed in a similar pose. Wang et al. [WHT07] propose a garment transfer method which overcame the constraint about the consistent mesh connectivity on reference models. Our work is mainly inspired by their work, in which they apply garment transfer to different poses. However, their method does not hold the key properties of garment transfer for various characters because they use only human as an input.

3. Our Approach

Our garment transfer process involves three steps. First, we measure the body shape of the target character (Section 3.1). Then, we transform the source clothing model to fit the target character (Section 3.2). Finally, we remove the distortion of the texture of the transferred clothing (Section 3.3).

3.1. Scale Calculation

Fitting affects the clothing shape considerably, as has been discussed in related work [CSMT03] [BSBC12]. The previous methods focused on clothing transfer between human models, and hence, it was sufficient to consider the absolute distance between
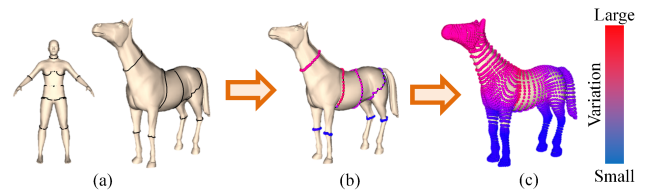
Figure 2: Pipeline of the scale calculation. First, we measure the length of the representative body parts (left), then calculate the scale proportion (middle), and finally propagate the scale proportion (right).
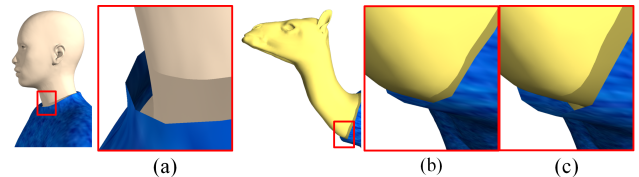
Figure 3: Comparison of the effect of the scaling term. (a) A source body and garment: (b) with no scale tweaking and (c) with scale tweaking.

the clothing and the body. Since our method transfers clothing from a human model to characters of different shapes and poses, the overall physical scales as well as the relative size of each body part of the source and target characters are very different. When a loose-fitting human garment is transferred to a big character such as a camel with the absolute distance between clothing and body preserved, the fit of clothing in the resulting model becomes too tight (see Figure 3(a)(b)). Although a simple scale measurement such as a bounding box can measure the overall size deviation, it is not sufficient for our purpose because the overall size does not account for the size deviation of each body part between two different characters. To take into account the variation of body shapes, we introduce a segment-wise relative scale measurement when transferring clothing to characters of different shapes and poses. When designing clothes in the real world, we measure the length of body parts along our body shape (i.e., geodesic loops). Therefore, we employ the geodesic line of the character body parts that are important for clothing design, such as bust, waist, and hips (see Figure 2(a)). We compute the proportion of the lengths between the characters with regard to each body part, and the proportion for each body part is assigned to vertices on the geodesic lines (Figure 2(b)). The proportion is propagated for the entire mesh by the following equation,

$$\min_{s_1, s_2, \cdots, s_n} \sum_{i=1}^{n} \left(s_i - \frac{1}{d_i} \sum_{j \in N(\vec{v}_i)} s_j \right)^2 \qquad (1)$$

where n is the number of body vertices, s_i is the assigned scale proportion at vertex $\vec{v}_i$, $\vec{v}_j$ is adjacent to $\vec{v}_i$, n_i is the number of one-ring neighborhood vertices of $\vec{v}_i$. The result of the scale calculation is shown in Figure 2(c). We use this proportion for the fitting error minimization (Section 3.2.2). Figure 3 shows that our scale calculation preserves the fitting of clothing between characters.

3.2. Clothing Transformation

Transferring clothing to a different character is challenging because it is difficult to compute the correspondence between a human and a character model. Although this has been researched previously, the character mesh is often not water-tight, making it difficult to calculate a bijection from the human to the character mesh. We propose a garment transfer technique without the need for one-to-one mapping between the meshes of characters. Ours is a generalized clothing transfer method because it can be applied even if character mesh is not water-tight. Therefore, instead of transferring clothing in a single optimization process [BSBC12], we divide this challenging task into two optimization processes. First, we transfer the coarse shape of clothing based on the correspondence between the two characters. Then, we adjust the fitting and remove distortion and penetration by minimizing a fitting error function.

3.2.1. Shape Transfer

According to the Deformation Transfer [SP04], we extract the deformation that transforms the source character to the target character, and apply it onto the source clothing. To compute the correspondences between the source and target triangle meshes, we use the energy-based method proposed in [SP04], which minimizes the difference between the target and deformed source model based on user-selected feature points. This optimization enables element-wise one-to-one correspondences between the source and deformed bodies, which ensures that the target is modeled as accurately as possible (see Figure 5). Let S_{s_j} be the deformation gradient of triangle j from the source body to the deformed source body and T_{t_j} be the deformation gradient from the source garment to the transferred garment. In order to minimize the difference between the deformation on the body and on the clothing, we solve the following minimization problem

$$\min_{\vec{y}_1, \vec{y}_2 \cdots, \vec{y}_n} \sum_{j=1}^{|M|} \|S_{s_j} - T_{t_j}\|_F^2 \qquad (2)$$

where M is the number of clothing mesh and $\vec{y}_1, \vec{y}_2 \cdots, \vec{y}_n$ are the vertices of the transferred garment. Figure 4(c) shows the result of our shape transfer. While the overall shape of the clothing fits the target, the resulting garment model does not look pleasant because of lack of detail such as interpenetration and unnatural deformation at the hems of the clothing.

3.2.2. Fitting Error Minimization

To solve the problem defined in 3.2.1, we introduce a fitting error function. While a similar fitting refinement method is proposed in DRAPE [GRH*12], their method does not reduce the distortion of the hem because they assume that the deviation of body shapes ranges within human body shapes. We modify cloth-body interpenetration term introduced in DRAPE, and add the term that preserves the design of its hem. Then, we solve the following linear least square problem:

$$E = \sum_{(i,j) \in C} \| - s_i \varepsilon_i + \vec{n}_{b_j}^T (\vec{y}_i - \vec{b}_j)\|^2 + \lambda_1 \sum_i \|\vec{y}_i - \vec{\hat{y}}_i\|^2 \qquad (3)$$

$$+ \lambda_2 \sum_{j=1}^{N} \sum_{i \in H_j} \|\vec{y}_i - (\vec{\hat{y}}_i + (s_i d_{src_i} - d_{trg_i})\vec{n}_j)\|^2$$
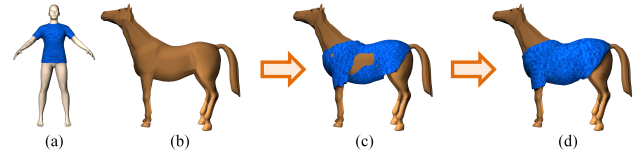
Figure 4: Pipeline of our clothing transformation from (a) a source to (b) a target body. (c) After applying shape transfer, (d) the fitting error minimization removes the penetration.
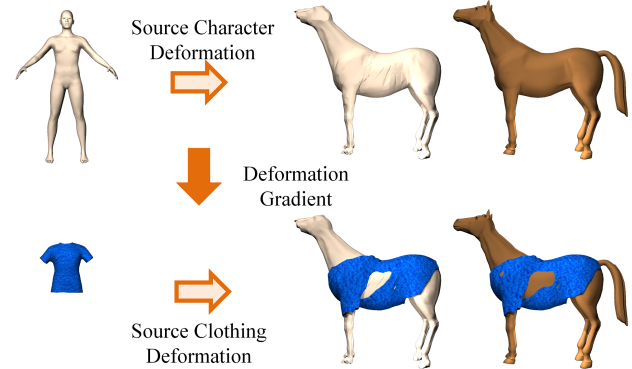
Figure 5: Overview of our shape transfer. The closest deformation from the source to the target body is applied to a clothing model.

where λ_1, λ_2 are the weights for each term, C is the set of correspondences between each garment vertex $\vec{y}_i$ and its closest body vertex $\vec{b}_j$, $\vec{n}_{b_j}$ is the normal vector for body vertex $\vec{b}_i$, s_i is the scale proportion obtained in Section 3.1 or $s_i = 1$ when transferring clothing between human models, ε_i is the distance between the source garment vertex $\vec{v}_i$ and its closest source body vertex; N is the number of hem, and H_i is the set of vertices of the ith hem. $\vec{n}_j$ is the normal vector of the plane on the basis of H_j. d_{trg_i} is the signed distance between the plane and $\vec{\hat{y}}_i$ and d_{src_i} is defined for source garment. For the first term, we modify DRAPE's cloth-body interpenetration term so that the fitting adjustment is aware of the segment-wise body proportion. The second term functions as a damping term. The third term preserves the original design of the hem such as collar and sleeves.

3.3. Texture Preservation

During the shape optimization processes, the assigned texture space is fixed for each triangle mesh, which results in a large distortion of the texture (see Figure 1(b)). Li et al. [LSNP13] propose a technique to simulate skin deformation in the texture space according to the character body deformation. However, they expressed the natural elastic deformation of the texture by simulating the skin and do not focus on preserving the texture for extremely large deformations. To achieve satisfactory appearance of the texture, we propose a method for deforming the texture on the transferred garment based on the spring-mass system. Our method not only uniformly preserves the texture on the transferred clothing, but also enables weighting of the region where the exact shape should be preserves, such as an appliqué or a logo.

3.3.1. Texture Space Deformation

While various methods for surface flattering (unwrapping) have been proposed, our system is mainly inspired by the ARAP-based surface flattering technique [II09] because it involves rigid control of the triangle shape in surface flattering. However, their method does not work well in our case because they focused only on applicable surface. Instead of a triangle face, we employ a mass-spring system, based on edge length (three edges of triangle) to define its distortion.

$$\min_{v' \in V} \sum_{i,j \in E} w_{ij} \|(v'_j - v'_i) - T_{ij}(v_j - v_i)\|^2 + \lambda \sum_i \|v'_i - v_i\|^2 \quad (4)$$

where w_{ij} is the weight for prioritization of the texture preservation; λ is the weights for each term; v'_i are texture vertices of the transferred garment; v_i are the texture vertices one iteration before; E is a set of edges, and T_{ij} is a scaling matrix based on the variation of the edge length between $(v_j - v_i)$ and $(v'_j - v'_i)$ in terms of the edge length. At each iteration, we update the texture vertices by solving the sparse least square problem (4). By updating the texture vertices with the damping term, we can prevent inversion of the elements around the seam of the transferred garment.
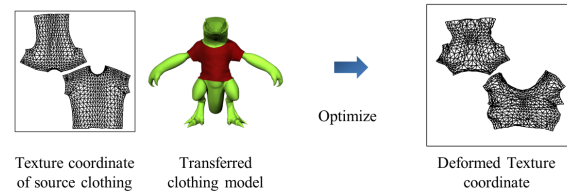
3.3.2. Weight Editing

For a large deformation, it is difficult to completely remove the texture distortion because the transferred garment cannot always be developed. Therefore, if we uniformly apply the texture preservation, the texture distortion still remains, which is unpleasant in particular around a logo. In order to prioritize the texture preservation for a specific region, we adjust the weight w_{ij} (Figure 7(d)).
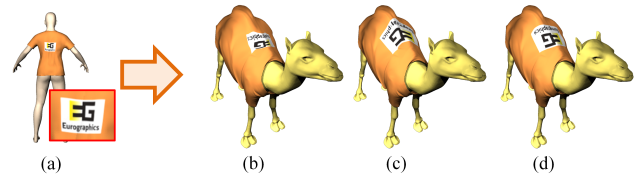
4. Result

The results generated by our garment transfer system show successful transfer of various kinds of clothing (Figure 8), e.g., with a whole pattern (Figure 1) or an appliqué pattern (Figure 7), to characters in various poses and shapes while preserving the fitting and texture. For virtual character with $17,000$ triangles and virtual garment with $1,400$ triangles, Scale Calculation process takes about 10 seconds, Clothing Transformation process takes 0.441 seconds, Texture Preservation process takes 0.248 seconds on a 64bit Windows PC (Intel®Core^{TM} i7-3630 CPU@2.40GHz;). Since the scale calculation result can be precomputed, we can process our algorithm rapidly when processing the other garment for the same character.

5. Conclusions

We propose a method to generate a clothing model for various characters from a single template garment model. To the best of our knowledge, our system is the first garment transfer system applicable to a wide variety of characters. Our novel framework consists of scale measurement, shape transformation method, and texture preservation technique. In future work, we would like to extend our method to wider varieties of clothing types such as loose fitting garments(e.g., skirt). Furthermore, we plan to explore a pattern paper generation technique for the resulting garment model so that we can fabricate clothing for pets or toys from our wardrobe. This would benefit not only artists but also manufacturing industries.

Figure 6: Overview of our texture preservation. Based on the deformation of transferred clothing, our system updates the texture coordinates.

Figure 7: The result of Texture Preserving (user weight editing) - (a) source body and garment. (b) Cloth transformation (Section 3.2). (c) texture preservation. (d) weight editing

Figure 8: Our model is applicable to challenging cases such as layered clothing.

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