Title:
Feature-based Human Model Matching for 3D Garment Transfer

Authors:
Bichen JING, bjing@connect.ust.hk, The Hong Kong University of Science and Technology, Beihang University
Matthew M.F. YUEN, meymf@ust.hk, The Hong Kong University of Science and Technology
Kai TANG, mektang@ust.hk, The Hong Kong University of Science and Technology
Gang ZHAO, zhaog@buaa.edu.cn, Beihang University

Keywords:
Feature-Based Modeling, Human Model Matching, Garment Transfer, Garment Fitting

DOI: 10.14733/cadconfP.2017.303-307

Introduction:
Virtual garment technology including 3D garment modeling and online virtual fitting regains people's attention with the development of e-commerce platforms. Although current garment CAD system with physics engine can generate fine garment mesh draped on human mesh, this method is still time- and labor-consuming to fulfill personalized online fitting demands due to the great number of garment styles and different sizes. To address this problem and improve virtual fitting efficiency, 3D garment transfer is studied to deform reference garment G_R and transpose it from a dressed reference human H_R onto a targeted human H_T. In this paper, a feature-based approach is introduced to match human models with different shape, pose and mesh topology, in order to drive garment deformation and help achieve plausible targeted human dressing effect.

The simplest human matching adopted by [3],[7] is one-one mesh vertex mapping for the meshes with same topology. Every mesh vertex of reference garment is projected onto nearest reference human triangle face and locally represented with attachment data [3]. Transposed garment is easily reconstructed via relocating garment vertex above targeted human, but scaled garment needs many successive geometric adjustments if size- or shape-preserving required. Lee et al. [5] match human by correlating sampled iso-contours regardless of mesh topology. The matching result guides garment torso part firstly transferred and other parts attached. The complicated sampling result on targeted human heavily depends on reference human and cannot be reused when changing the reference data. Zhang et al. [9] describe another topology-independent human matching via constructing segmented proxy meshes for targeted human using reference human mesh topology, based on which garment can be fitted similar to [3]. However, a T-pose is necessary for every human model due to its human segmentation strategy. Brouet et al. [2] link human models and garment model with embedded skeletons that garment vertex can be represented and relocated using offset vectors emitting from projection points on skeletons. The human pose in this work needs to be consistent to make garment model proportionally scale. Li et al. [6] directly dress an independent 3D garment onto targeted human through volumetric Laplacian deformation to match predefined garment skeleton with human skeleton. For 3D garment model without human support, it needs a wealth of experience to locate and adjust garment skeleton properly. To dress a targeted human with any shape and any pose, Guan et al. [4] learn a garment model from several simulated dressed human models selected via matching shape- and pose-parameters in trained examples. This data-driven strategy needs to construct large simulated dataset for specific garment model, which costs too much for variant garment styles. Compared with prior works, our approach will separately parameterize each human model according to consistent semantic feature configuration and match models at feature level enabling flexible choice of human

Proceedings of CAD'17, Okayama, Japan, August 10-12, 2017, 303-307

shapes, poses and skeleton dimensions. Besides, the matching algorithm matches each reference human mesh vertex to a mapping vertex on targeted human mesh without imposing a strict one-one vertex correspondence requirement. As discussed, human matching result drives garment transfer effect. Through manipulating human mesh vertex parameters, transferred garment shape will be adjusted catering for both size- and shape-preserving transfer.

Main Idea:

In this paper, human models with skeletons share same topological feature configuration enabling consistent model segmentation regardless of human shape, pose and mesh topology. Geometric relationship between corresponding features of two human models is defined through proposed human matching algorithm. Garment model is linked with human features and geometrically transferred using obtained model correlation information under size- or shape-constraint. Fig. 1 illustrates a systematic workflow for garment transfer. In this figure, a reference database is prebuilt consisting of reference human H_R and reference garments G_R. Every G_R is physically draped on H_R and linked with human features only once. For any input targeted human H_T, it needs an embedded skeleton and to be segmented following H_R feature configuration. To generate a plausible transferred garment G_T, some post processing techniques are needed, such as geometric collision detection and handling, strain limiting and smoothing.

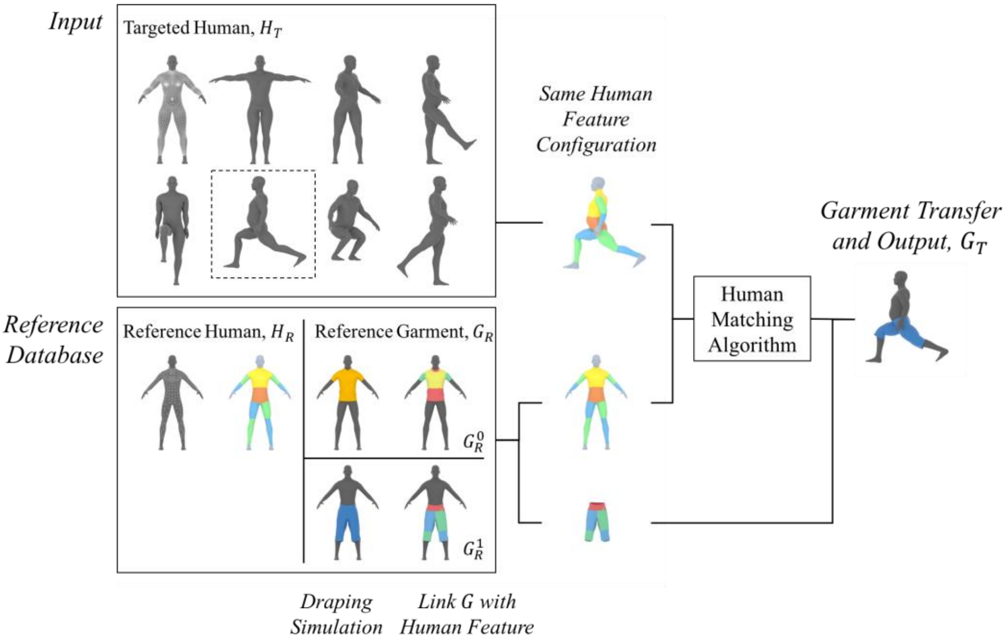

Fig. 1: Feature-based garment transfer workflow.

Feature Human Model Definition

Three-level feature human model is designed shown in Fig. 2 according to [1] that human is defined as object at top level representing a class sharing same topology. The feature topological graph forms the object feature configuration consisting of feature skeletons with attributes. The model's geometric form is consistently segmented according to feature graph, which can be achieved by [8]. Each segmented patch is assigned to corresponding feature as feature geometry at bottom level.

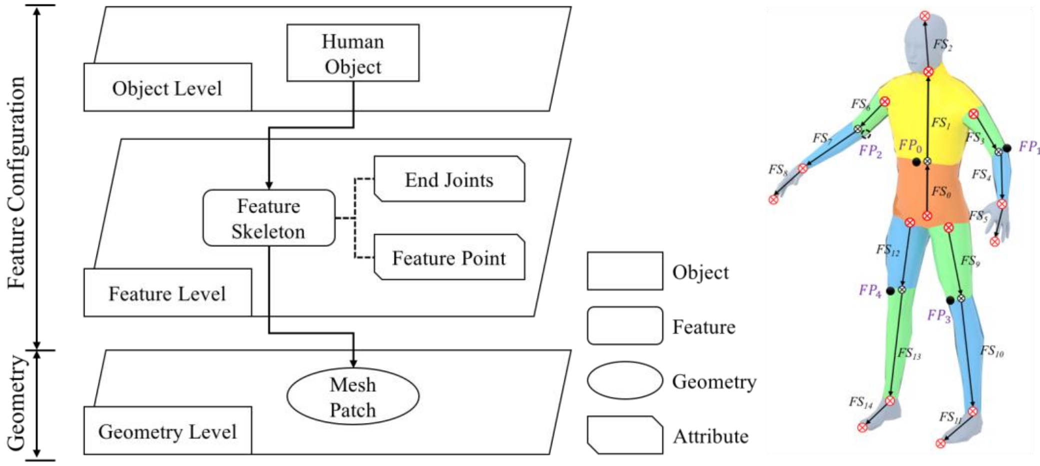

Fig. 2: Left: Feature Human Model; Right: Feature Skeleton, End Joints and Feature Points.

Human Matching Scheme

Reference garment is linked with reference human and human matching result drives garment deformation. In this work, garment model is linked with human at vertex level that each garment vertex is locally represented by human vertices and a projection position on skeleton. Thus, the purpose of human matching is to link each reference human vertex with a corresponding position on targeted human mesh. Since it is difficult to locate a proper position on targeted human for reference human vertex in 3D space, we will map corresponding features into a same parameter domain and match through searching.

As described in introduction, human model is respectively parameterized at feature level then matched with another one. To parameterize vertices within a skeleton feature, the skeleton is assigned an orientation. For each human vertex belonging to this cylinder-like feature skeleton, we project the vertex onto skeleton and connect this vertex with projection using a line-segment, and there exists a plane passing the line and perpendicular to the skeleton. One parameter of vertex is length l defined as the distance on skeleton from projection position to the starting joint position of skeleton. Another parameter is angle a measured between line-segment and a reference plane determined by attribute feature point and end joints. An example is shown in Fig. 3 (c) that human vertex v_H in FS_0 is projected onto FJ_0FJ_1, so that $l = \left\| v_H^{proj} \mathrm{FJ}_0 \right\|$. Angle parameter a is measured following right-hand rule around directional skeleton while the measurement reference plane is determined by FJ_0, FJ_1 and FP_0. Fig. 3(a), Fig. 3(b), Fig. 3(d), Fig. 3(e) show FS_0 parameterization results of H_R and H_T with different mesh topology.

After obtaining vertex parameters for corresponding features of two human models, the parameters of targeted feature form a searching space for each reference vertex to find a nearest neighbor and set it as mapped vertex. In Fig. 3 (f), red points indicate parameters of reference feature while blue points indicate targeted ones. For each red point, we want to find a nearest blue point and match original two 3D vertices. Since two parameters have different units, human model matching has two strategies to set searching space coordinates catering for both size-preserving and design-preserving garment transfer. Size-preserving transfer uses distance along skeleton as key factor to correlate garment and human models, so that l is adopted as one coordinate. To unify coordinate units for nearest neighbor searching, the other coordinate is derived from angle a by multiplying a factor that $l_a = a \times C / 360$, while C is average circumference perpendicular to skeleton in a feature. In our implementation, we simply use the circumference passing feature point to calculate l_a, for example C_0 in Fig. 3 (c) is adopted to calculate l_a for v_H. Design-preserving transfer uses proportion on skeleton divided by vertex projection as key factor to correlate models, so l/l_s is adopted as one coordinate. To unify coordinate units for searching, angle a is normalized to [0, 1].

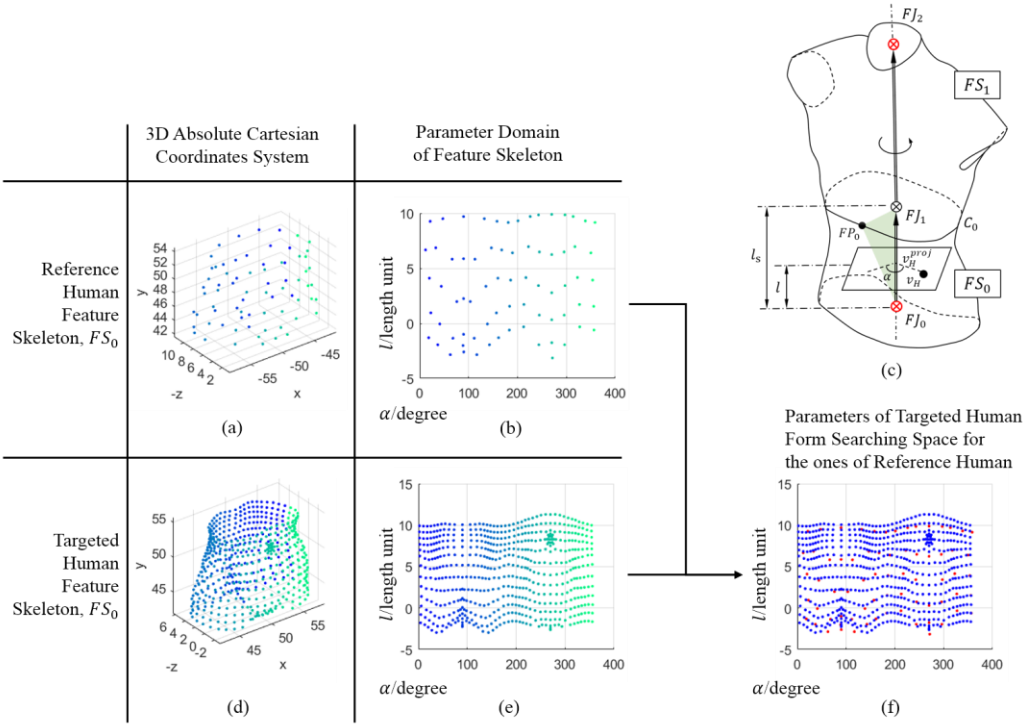

Fig. 3: (a), (b) FS_0 Parameterization of H_R; (d), (e) FS_0 Parameterization of H_T; (f) Vertex Matching in Parameter Domain for Size-Preserving Garment Transfer; (c) Parameterization of Vertex in FS_0.

Link Garment with Human and Transfer

Garment model is linked with both reference human mesh and skeleton by projecting each garment vertex onto a nearest skeleton and find intersection point on mesh, illustrated in Fig. 4. Then Garment mesh can be locally represented at vertex-level and transferred on targeted human through an inverse process using human matching result. To improve garment plausibility, techniques such as collision handling and strain limiting are needed.

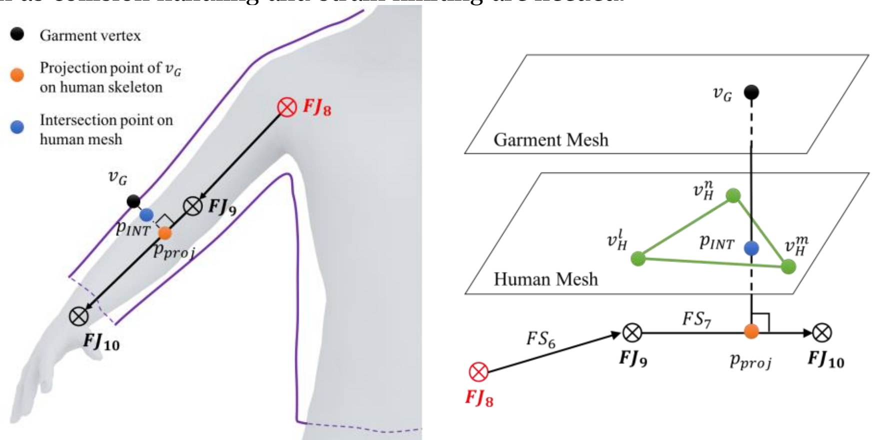

Fig. 4: Link Garment Model with Underlying Human Model.

Conclusions:

A feature based matching scheme is presented for mesh-inconsistent, shape- and pose-independent human models catering for garment transfer oriented applications. An experiment result of size-preserving garment transfer are shown in Fig. 5 that after matching two women models using our approach, reference garment G_R^0 and G_R^1 are geometrically transferred onto a pregnant woman preserving their sizes using strain limiting. The overlapping relationship is prescribed and overlapping effect is achieved by collision handling. With the help of this scheme, constructed and draped garment model can be fast and automatically transferred onto another human model which greatly enhances the reusability of 3D garment model and improve the efficiency of garment preposition before simulation.

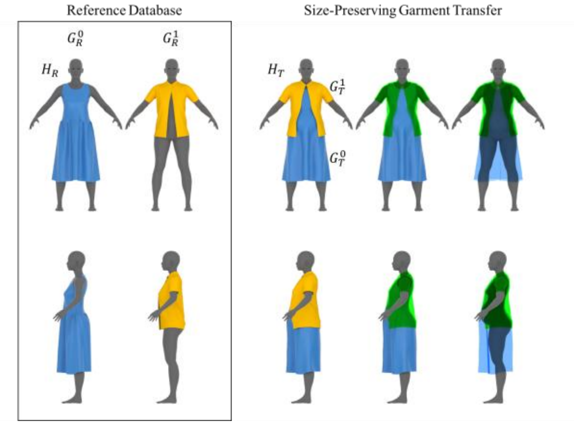

Fig. 5: Transfer Multiple Garments and Preserve Size after Human Matching.

Acknowledgements:
Authors from HKUST are partially supported by Hong Kong Research Grants Council Fund 1612214.

References:
[1] Au, C. K.; Yuen, M. M.: A semantic feature language for sculptured object modelling, Computer-Aided Design, 32(1), 2000, 63-74. http://doi.org/10.1016/S0010-4485(99)00085-8
[2] Brouet, R.; Sheffer, A.; Boissieux, L.; Cani, M.: Design preserving garment transfer, ACM Transactions on Graphics (TOG), 31(4), 2012, 36. http://doi.org/10.1145/2185520.2185532
[3] Cordier, F.; Seo, H.; Magnenat-Thalmann, N.: Made-to-measure technologies for an online clothing store, IEEE Computer Graphics and Applications, 23(1), 2003, 38-48. http://doi.org/10.1109/MCG.2003.1159612
[4] Guan, P.; Reiss, L.; Hirshberg, D. A.; Weiss, A.; Black, M. J.: DRAPE: DRessing any Person; ACM Trans.Graph., 31(4), 2012, 35. http://doi.org/10.1145/2185520.2185531
[5] Lee, Y.; Ma, J.; Choi, S.: Automatic pose-independent 3D garment fitting, Computers & Graphics, 37(7), 2013, 911-922. http://doi.org/10.1016/j.cag.2013.07.005
[6] Li, J.; Ye, J.; Wang, Y.; Bai, L.; Lu, G.: Fitting 3D garment models onto individual human models, Computers & Graphics, 34(6), 2010, 742-755. http://doi.org/10.1016/j.cag.2010.07.008
[7] Meng, Y.; Wang, C. C.; Jin, X.: Flexible shape control for automatic resizing of apparel products, Computer-Aided Design, 44(1), 2012, 68-76. http://doi.org/10.1016/j.cad.2010.11.008
[8] Yan, H.; Hu, S.; Martin, R. R.; Yang, Y.: Shape deformation using a skeleton to drive simplex transformations, Visualization and Computer Graphics, IEEE Transactions on, 14(3), 2008, 693-706. http://doi.org/10.1109/TVCG.2008.28
[9] Zhang, M.; Lin, L.; Pan, Z.; Xiang, N.: Topology-independent 3D garment fitting for virtual clothing, Multimedia Tools and Applications, 74(9), 2015, 3137-3153. http://doi.org/10.1007/s11042-013-1774-4