Towards Cloth-Manipulating Characters

Eder Miguel

URJC Madrid

eder.miguel@gmail.com

Andrew Feng

USC Institute for Creative Technologies

feng@ict.usc.edu

Ari Shapiro

USC Institute for Creative Technologies

shapiro@ict.usc.edu

Abstract

Cloth manipulation is a common action in humans that many animated characters in interactive simulations are not able to perform due to its complexity. In this paper we focus on dressing-up, a common action involving cloth. We identify the steps required to perform the task and describe the systems responsible for each of them. Our results show a character that is able to put on a scarf and react to cloth collision and over-stretching events. Based on our experiments, we recommend a number of changes to a cloth-character model that would expand the capabilities of such interactions.

Keywords: image capture, animation, avatar

1 Introduction

Realistic animation of different character behaviors such as locomotion, reaching or gestures can be obtained using current animation engines. Object manipulation is another interesting behavior that involves not only the character but also the object being manipulated. Most of the approaches to manipulate objects are designed to work with rigid bodies, whose behavior is quite predictable. In contrast, the behavior of deformable objects, and specially cloth, is completely unpredictable making it a difficult problem as shown by the almost non-existent literature. Most state of the art in cloth manipulation can be found in robotics, where research has focused on specific tasks such as folding [1] or clothing assistance [2].

In this paper we present a first approach to an animation engine capable of manipulating cloth and react to events such as collisions. We have focused on dressing-up because it is a complex action that requires the interaction of many of the systems necessary for almost any other type of cloth manipulation.

2 Related Work

We will first discuss related work on cloth modeling in computer graphics and then review other relevant work on general object manipulation and cloth manipulation.

Clothing in computer graphics has been a very active research topic for decades [3, 4]. In the last few years researchers have put great efforts in developing more realistic cloth models [5, 6], design tools [7], faster simulation techniques [8, 9] and procedures to automatically dress virtual characters [10, 11].

In these previous works, the most common interaction between virtual characters and cloth or garments comes in the form of scenes where dressed characters move and clothing reacts to the characters' motion. However, this is a very limited form of interaction: the character is not manipulating the cloth since it has no specific goal.

Object manipulation is a field for which a large amount of state of the art is available. Yamane et al. [12] combine path planning, inverse kinematics and motion capture data to obtain natural animations while manipulating objects. Kallmann and Thalmann [13] proposed the *smart object* approach to store object manipulation information as part of an object description. Feng et al. [14] use motion blending and locomotion to reach objects outside of the character's inmediate reach. Bai et al. [15] use dynamics of the upper body to adjust to objects being carried on the character. However, despite the availability of all these previous works, cloth manipulation requires different approaches due to its complex and highly dynamic behavior.

While previous work on cloth manipulation is almost non-existent in computer graphics and animation, we found several references in robotics. Cusumano-Towner et al. [16] describe a procedure for a robot to autonomously bring clothing into desired configurations. In [1], Lakshmanan et al. present an algorithm for robotic cloth folding. Tamei et al. [2]

propose a system that assists people while clothing.

Our goals differ from most previous work; we attempt to identify the elements of a proper character-to-cloth model in pursuit of emergent character behavior as it is affected by the clothing.

3 Character Dress-Up System

Approaching. The overall dress-up system is described in Fig. 1. The first step for a virtual character to put on clothing is to move within a given reach distance from the piece of clothing to manipulate. This implies that a locomotion system must be integrated.

Grasping and Posing. Once the character is within that reach distance, it must first grasp the cloth and then reach the initial pose from which the putting on phase will start. Both grasping and posing involve continuous planning to adapt the hand motion to the dynamically changing surface of the cloth, as well as a reaching system able to generate realistic full body reach motions.

Different types of cloths are grasped differently. In order to allow the system to evolve correctly, simple cloth objects, such as the scarf seen in our demos, must include definitions of grasping areas. However, more complex garments, such as shirts or trousers, may also require sequencing information that specifies grasping order and/or handedness.

After properly grasping the cloth, the system evolves to bring it to the specified initial pose from which the putting on phase will start. This initial pose depends on the type of garment and should be defined relative to the anatomy of the character, i.e. relative to bone lengths and/or inter-joint distances, so that the system works properly for a variety of characters. In the scarf demo, shoulder joints positions and shoulder-elbow distance are used as references for the character to pose the cloth initially.

Grasping and posing will set the cloth into motion, requiring accurate dynamic simulation and collision detection and response. These tasks must be handled by a physics simulator. In addition to handling these tasks, the simulator outputs information relevant to the dressing-up process such as contact points and cloth stress values.

Putting On. The putting on phase starts from the initial pose. The system drives the character using parameterized captured motions that are blended and sequenced based on feedback from the cloth, such as collision or over-stretching events. Parameters are computed at runtime depending on this feedback as well as the distance from a specified reference path for joints motion and a reference final configuration.

Collision and over-stretching events contain information about the position where they took place, as well as stress values in the case of over-stretching events. These stress values will be compared to specified material-dependent threshold stress values in order to generate the over-stretching events.

The reference joint motion path used to guide the character while putting on garments depends on the type of garment. For a simple garment, such as a scarf, no path is necessary. However, more complex garments, such as shirts, require certain joints to traverse a given path, such as wrist and elbow joints traversing a path inside the sleeves.

Finally, during the putting on phase the character may run into complex series of events that may require undoing the latest actions. In our example, we deal with this problem by playing backwards the captured motions, but for other types of garments this may not be possible and different capture motions for undressing may be necessary.

4 Demo and Results

Using the system described in the previous section, Fig. 2 shows an animated character that is able to put on scarves with different properties and dynamic behaviors and react to events, such as collisions with the head. We have used Bullet [17] as the physics engine, which allows us to obtain a real-time cloth simulation at the cost of less accurate collision handling. For the locomotion, reaching and posing, grasping and motion blending systems we have used Smartbody [18] animation engine.

Compared to the scheme in Fig. 1, the system used in this example lacks several features. No grasping and posing planning has been used since a simple trial and error approach works. No reference motion path is needed for a scarf, and the final configuration is assumed to be correct if the motion has finished.

5 Discussion

Our experiments with character-to-cloth manipulation guide us towards enhancements and changes to interactive models that intend to accommodate such interactions:

Proper grasping/holding areas for cloth. Clothing that is to be manipulated by a virtual character requires information about where the clothing article must be held or grasped in order to properly manipulate it. For example, pants need to be held at the belt level to be put on properly, hats need to be grasped on the outside, scarves must be grabbed near their ends. The virtual character will need to bring their hands to the proper position before the donning process will function properly.

Feedback to character of proper vs improper cloth contact. Contact between the cloth and the character is detected as a collision between the cloth and the character. However, in the context of wearing clothing, some such contact is irrelevant to the character, while others will yield a response from the character. For example, a properly worn shirt and an improperly worn shirt would both have continuous contact with a character, but only, for example, an unbuttoned shirt cuff would necessitate a response from the character. Thus, it is necessary to distinguish between contact of properly worn clothing versus improperly worn clothing. Such difference is important as a trigger to modify a character's behavior.

Improved model of cloth stress and tension. Other than mesh-to-mesh contact, a virtual character should be aware of the tension of clothing as it relates to donning or wearing of the clothing. Thus, the coupling movement, energy usage, and tension of the cloth would be important as it relates to restriction of movement or discomfort. For example, a tight skirt would restrict leg movement, or the placing of an arm through a sleeve in an improper direction would lead to tension from the cloth, which should trigger a response from the character, either to change the path of movement, or to perform some other corrective action.

We describe an experiment where we attempt to couple an interactive character with clothing. We attempt to understand the elements of character-to-cloth interaction that need to be accommodated for interactive character to put on and take off clothing. In doing so, we envision more detailed modeled of cloth and clothing, and subsequently more interactions between a virtual character and their clothing. We anticipate that such models will allow characters to put on, take off and adjust clothing on their body. As such, clothing becomes an active agent in such a simulation, instead of a passive one, we expect changes in a character's behavior to emerge, related to movement, posture and actions. For example, a hat that falls too far down the character's face should motivate the character to tip the hat backwards, or clothing that is overly restrictive or tight should similarly restrict the movements of a character.

References

[1] Karthik Lakshmanan, Apoorva Sachdev, Ziang Xie, Dmitry Berenson, Ken Goldberg, and Pieter Abbeel. A constraint-aware motion planning algorithm for robotic folding of clothes. In *Experimental Robotics*. 2013.

[2] T. Tamei, T. Matsubara, A. Rai, and T. Shibata. Reinforcement learning of clothing assistance with a dual-arm robot. In *Humanoid Robots (Humanoids), 2011 11th IEEE-RAS International Conference on*, 2011.

[3] Demetri Terzopoulos, John Platt, Alan Barr, and Kurt Fleischer. Elastically deformable models. In *ACM Siggraph Computer Graphics*, volume 21, pages 205–214. ACM, 1987.

[4] David Baraff and Andrew Witkin. Large steps in cloth simulation. In *Proceedings of the 25th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '98, pages 43–54, New York, NY, USA, 1998. ACM.

[5] Jonathan M. Kaldor, Doug L. James, and Steve Marschner. Simulating knitted cloth at the yarn level. *ACM Trans. Graph.*, 27(3):65:1–65:9, August 2008.

[6] Huamin Wang, James F. O'Brien, and Ravi Ramamoorthi. Data-driven elastic models for cloth: Modeling and measurement. *ACM Trans. Graph.*, 30(4):71:1–71:12, July 2011.

[7] Nobuyuki Umetani, Danny M. Kaufman, Takeo Igarashi, and Eitan Grinspun. Sensitive couture for interactive garment modeling and editing. *ACM Trans. Graph.*, 30(4):90:1–90:12, July 2011.

[8] Doyub Kim, Woojong Koh, Rahul Narain, Kayvon Fatahalian, Adrien Treuille, and James F. O'Brien. Near-exhaustive precomputation of secondary cloth effects. *ACM Trans. Graph.*, 32(4):87:1–87:8, July 2013.

[9] Tiantian Liu, Adam W. Bargteil, James F. O'Brien, and Ladislav Kavan. Fast simulation of mass-spring systems. *ACM Trans. Graph.*, 32(6):214:1–214:7, November 2013.

[10] Peng Guan, Loretta Reiss, David A. Hirshberg, Alexander Weiss, and Michael J. Black. Drape: Dressing any person. *ACM Trans. Graph.*, 31(4):35:1–35:10, July 2012.

[11] Yongjoon Lee, Jaehwan Ma, and Sunghee Choi. Technical section: Automatic pose-independent 3d garment fitting. *Comput. Graph.*, 37(7):911–922, November 2013.

[12] Katsu Yamane, James J Kuffner, and Jessica K Hodgins. Synthesizing animations of human manipulation tasks. In *ACM Transactions on Graphics (TOG)*, volume 23, pages 532–539. ACM, 2004.

[13] Marcelo Kallmann and Daniel Thalmann. Direct 3d interaction with smart objects. In *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, VRST '99, pages 124–130, New York, NY, USA, 1999. ACM.

[14] Andrew W Feng, Yuyu Xu, and Ari Shapiro. An example-based motion synthesis technique for locomotion and object manipulation. In *Proceedings of the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games*, pages 95–102. ACM, 2012.

[15] Yunfei Bai, Kristin Siu, and C Karen Liu. Synthesis of concurrent object manipulation tasks. *ACM Transactions on Graphics (TOG)*, 31(6):156, 2012.

[16] Marco Cusumano-Towner, Arjun Singh, Stephen Miller, James F O'Brien, and Pieter Abbeel. Bringing clothing into desired configurations with limited perception. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 3893–3900. IEEE, 2011.

[17] Erwin Coumans et al. Bullet physics library. *Open source: bulletphysics. org*, 2006.

[18] Ari Shapiro. Building a character animation system. In JanM. Allbeck and Petros Faloutsos, editors, *Motion in Games*, volume 7060 of *Lecture Notes in Computer Science*, pages 98–109. Springer Berlin Heidelberg, 2011.

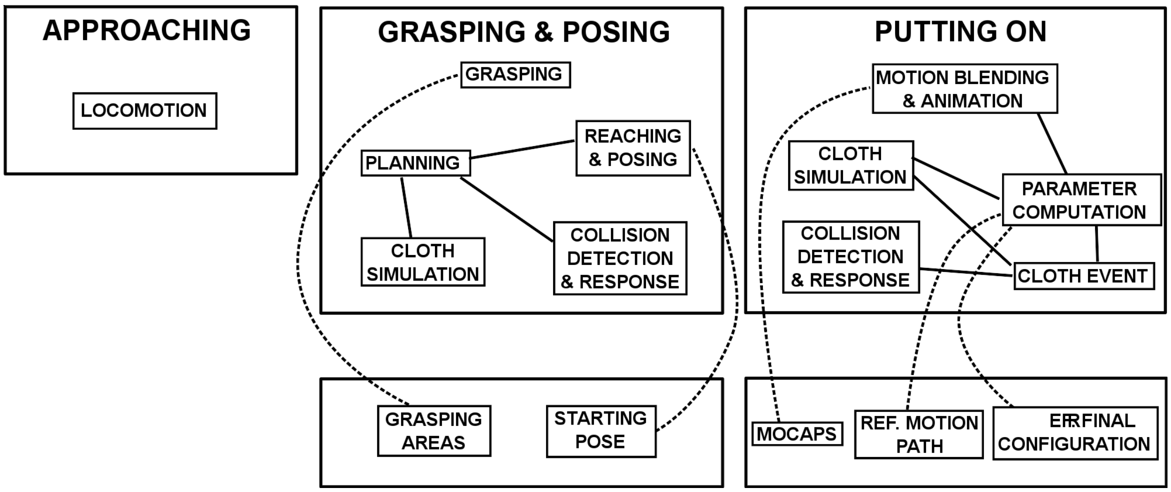

Figure 1: Schematic overview of dressing-up process: sequence of steps, systems involved and data required by each of them.

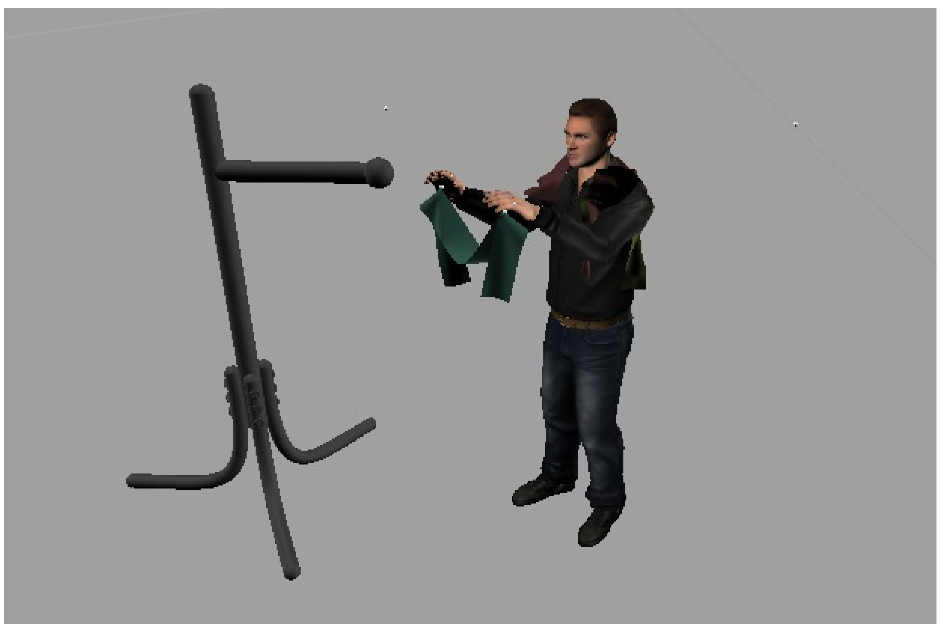

Figure 2: Character wearing two scarfs and trying to put on another one.