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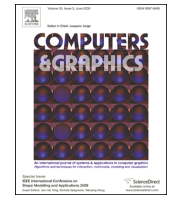

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Representing mesh-based character animations

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ABSTRACT

We propose a new approach to represent and manipulate a mesh-based character animation preserving its time-varying details. Our method first decomposes the input mesh animation into coarse and fine deformation components. A model for the coarse deformations is constructed by an underlying kinematic skeleton structure and blending skinning weights. Thereafter, a non-linear probabilistic model is used to encode the fine time-varying details of the input animation. The user can manipulate the corresponding skeleton-based component of the input, which can be done by any standard animation package, and the final result is generated including its important time-varying details. By converting an input sample animation into our new hybrid representation, we are able to maintain the flexibility of mesh-based methods during animation creation while allowing for practical manipulations using the standard skeleton-based paradigm. We demonstrate the performance of our method by converting and manipulating several mesh animations generated by different performance capture approaches and apply it to represent and manipulate cloth simulation data.

1. Introduction

Recently, a variety of mesh-based approaches have been developed to enable the generation of computer animations without relying on the classical skeleton-based paradigm [1,2]. The advantage of a deformable model representation is also demonstrated by the new performance capture approaches [3,4], where both motion and surface deformations can be captured from input video-streams for arbitrary subjects. This shows the great flexibility of a mesh-based representation over the classical one during animation creation.

Although bypassing many drawbacks of the conventional animation pipeline, a mesh-based representation for character animation is still complex to be edited or manipulated. Few solutions are presented in the literature [5–9], but in general it is still hard to integrate these methods into the conventional pipeline. Other approaches try to convert or represent mesh animations using a skeleton-based representation to simplify the rendering [10] or editing tasks [11,3]. However, these editing methods are not able to preserve fine time-varying details during the manipulation process, as for instance the waving of the clothes for a performing subject.

For editing mesh-based character animations, an underlying representation (i.e. skeleton) is desired since it simplifies the overall process. At the same time, the time-varying details should be preserved during manipulation. These two constraints guide the design of our new hybrid representation for mesh-based character animation. Our method decomposes the input mesh animation into coarse and fine deformation components. A model for the coarse deformation is constructed automatically using the conventional skeleton-based paradigm (i.e. kinematic skeleton, joint parameters and blending skinning weights). Thereafter, a model to encode the time-varying details is built by learning the fine deformations of the input over time using a pair of linked Gaussian process latent variable models (GPLVM [12]). Our probabilistic non-linear formulation allows us to represent the time-varying details as a function of the underlying skeletal motion as well as to generalize to different configurations such that we are able to reconstruct details for edited poses that were not used during training. By combining both models, we simplify the editing process: animators can work directly using the underlying skeleton and the corresponding time-varying details are reconstructed in the final edited animation.

We demonstrate the performance of our approach by performing a variety of edits to mesh animations generated from different performance capture methods. Additionally, we extend the original approach [13] to represent and manipulate cloth simulation data. As a result, our technique is also able to convert cloth animation into a new hybrid representation that is more flexible for editing purposes and it can be easily integrated in the conventional animation pipeline (Section 7).

The paper is structured as follows: Section 2 reviews the most relevant related work and Section 3 briefly describes our overall

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approach. Thereafter, Section 4 details the method to convert a mesh-based character animation into the skeleton-based format and Section 5 describes how the time-varying details are learnt using a non-linear probabilistic technique. Experiments with mesh-based character animations are shown in Section 6, applications of the extended technique for cloth simulation is presented in Section 7 and the paper concludes with a discussion about the approach in Section 8.

2. Related work

Creating animations for human subjects is a time-consuming and expensive task. In the traditional framework, the character animation is represented by a surface mesh and an underlying skeleton. The surface geometry can be hand-crafted or scanned from a real subject and the underlying skeleton is manually created, inferred from marker trajectories [14] or inferred from the input geometry [15,16]. The skeleton model is animated by assigning motion parameters to the joints and the geometry and skeleton are connected via skinning (see [17] for an overview).

Given the complexity of this process, many related methods have been developed to simplify this pipeline, bypassing many drawbacks of the conventional framework [1]. In particular, the recent progress of deformation transfer [18,19], surface capture [20,21] and mesh-based performance capture methods [3,4] is enabling the creation of an increasing number of mesh-based animations for human subjects. As a result, editing and reusing these animations is becoming an important issue.

A number of approaches have been developed to process and edit general mesh animations [5–9], but unfortunately these methods cannot be easily used by animators or integrated into the conventional animation pipeline. For animations that can be represented by an underlying kinematic skeleton, e.g. human subjects, an underlying representation is more flexible for editing operations, it enables its integration into a conventional animation package and it simplifies the overall process.

Recent techniques to simplify the rendering task for such mesh animations [10], mesh-based animation compression techniques [22–24] and new methods to convert a sequence of mesh poses [11] or mesh animations [3] to a skeleton-based format have been investigated. The approach proposed in [13] extends these latter editing approaches by preserving the fine time-varying details during the manipulation process, which increases the quality of the final result (Fig. 1).

Example-based skinning methods attempt to improve simple linear deformation by adding or correcting surface details from a given set of examples. In case when the animation edits are not too large or complex, pose-space deformation [25,26], weighted pose space deformations [27], and related approaches would be able to provide reasonable results. Similar techniques have been developed for face animation [28,29] as well. In the proposed framework [13], surface time-varying details are encoded and preserved by a non-linear probabilistic technique. In contrast to related approaches dealing with human skin deformations [30–32], our method is even able to model deformations of loose apparel.

Considering that the underlying subspace of deformations is inherently non-linear, we believe that a non-linear dimensionality technique is appropriate to compactly represent these deformations. Among the non-linear dimensionality reduction approaches, Gaussian Process Latent Variable Models (GPLVM [12,33]) have been shown to generalize well from small training sets and they do not tend to over-fit as other techniques. Recently, a variety of GPLVM approaches have been widely used for learning human motion either using a dynamic representation [34] or a shared latent structure [35]. These techniques were also used to model large dimensional data, such as silhouettes [36], voxel data [37], simple deformable models [38] and even mesh-based character animations [13].

Our system extends the technique proposed in [13] to represent and manipulate cloth simulation data as well. Recently, a variety of techniques have been developed to enable the use of cloth animation in games or interactive applications using data-driven techniques [39–42]. We follow this direction to extend our system to be able to represent and manipulate mesh-based cloth simulation data. As a result, the system can be used to render cloth animation in real-time or it can be used to manipulate cloth simulation data.

3. Overview

An overview of our approach is shown in Fig. 2. The input to our method is an animated mesh sequence comprising N_{FR} frames. The mesh-based character animation, or the cloth simulation data, $(MCA = [M, p_t])$ is represented by a sequence of triangle mesh models $M = (V = vertices, T = triangulation)$ and position data $p_t(v_i) = (x_i, y_i, z_i)_t$ for each vertex $v_i \in V$ at all time steps t.

Our framework is inspired by Botsch and Kobbelt [43], where a new representation for mesh editing is proposed using a multi-resolution strategy. In contrast to their method, our system can be applied to a sequence of spatio-temporally coherent meshes and it allows the manipulation of the entire animation by decomposing it into coarse (MCA_C) and fine (MCA_F) deformation components. A model for coarse deformations is created by automatically fitting a kinematic skeleton to the input and by calculating the joint

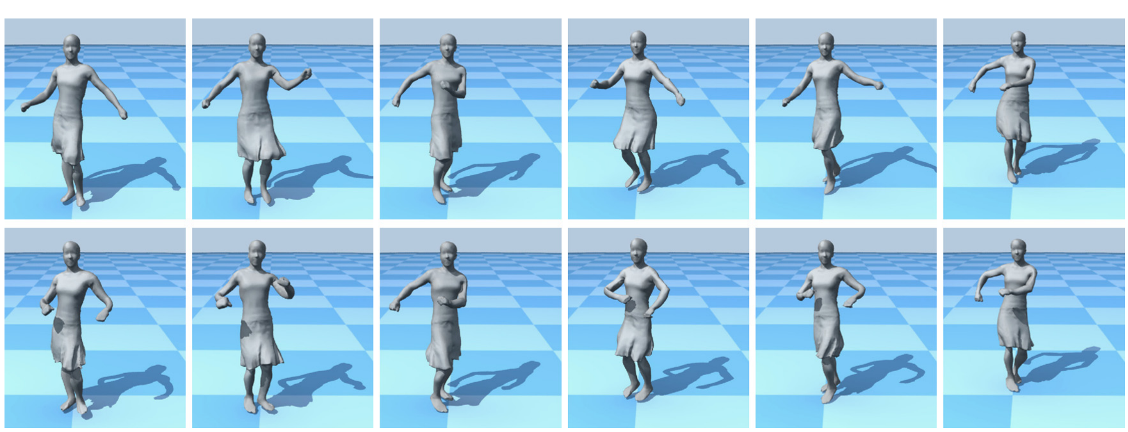

Fig. 1. Our approach represents an input mesh-based character animation (top row – particular frames) into a new hybrid representation that simplifies the editing process and preserves important time-varying details, i.e. dynamics of the skirt (bottom row – edited frames).