Motion Compression using Principal Geodesics Analysis

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Abstract

We present a novel, lossy compression method for human motion data that exploits both temporal and spatial coherence. We first build a compact skeleton pose model from a single motion using Principal Geodesic Analysis(PGA). The key idea is to perform compression by only storing the model parameters along with the end-joints and root joint trajectories in the output data. The input data are recovered by optimizing PGA variables to match end-effectors positions in an inverse kinematics approach. Our experimental results show that considerable compression rates can be obtained using our method, with few reconstruction and perceptual errors. Thanks to the embedding of the pose model, our system can also be suitable for motion editing purposes.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism–Animation I.2.10 [Vision and Scene Understanding]: Motion

1. Introduction and Related work

Motion capture has became a ubiquitous technique in any domain that requires high quality, accurate human motion data. With the outcome of massively multiplayer online games as well as the ever-increasing level-of-details present in these productions, the transmission and storage of huge quantities of motion data has became an important issue. While raw motion capture data are very large, human motion exhibits inherent redundancies that can be exploited for compression purposes:

- **Temporal coherence**, thanks to which the motion can be keyframed with few loss of information,
- **Joints motion correlations**, which allows the representation of the motion in a smaller subspace.

Research work on motion compression has mainly been focused on meshes compression so far, due to the high level of redundancies and correlations present in those data. However, recent works such as [LM06], [Ari06] tackle the skeleton motion capture data compression problem with promising results. Most of them acheive compression by expoiting both temporal and spatial coherence in global markers positions using Principal Component Analysis (PCA) and spline interpolation. Our approach is to work with joint orientations, so that bone-length remains constant throughout the compression pipeline. In this purpose, we use non-linear multiresolution analysis such as [RDS*05], as well as non-linear statistical descriptive analysis, namely Principal Geodesic Analysis (PGA, [FLJ03]). PGA is an extension of PCA to the case of data lying in certain curved manifolds, such as orientation space $SO(3)$. The data are projected onto geodesics instead of straight lines, so that no deviation from the manifold occurs during the process.

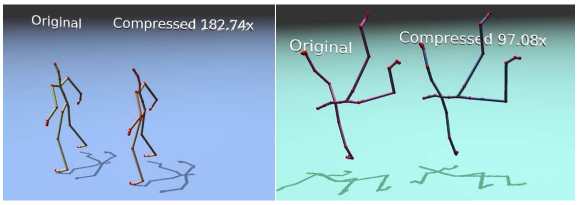

Figure 1: *Sample compressed animations*

2. Proposed Method

We begin by building a compact pose model out of one motion using PGA. The PGA yields a set of k tangent vectors $(v_j)_{j<k}$ to some manifold M so that the original data can be reconstructed approximately using the exponential map by:

$$p = \mu. \prod_{j=1}^{j=k} e^{t_j.v_j}$$

where μ is the intrinsic mean of the data [FLJ03], and $t_j \in \mathbb{R}$ is the projection of p onto the j^{th} geodesic. The principal tangent directions can be approximated by linearizing the data in the tangent space of the manifold at μ, then applying standard PCA on the tangent data. We extract principal geodesics out of the pose data (elements of $SO(3)^n$, where n is the number of inner joints). These geodesics can be thought of as eigenposes that best describe the input poses. As for PCA compression, we only keep the leading eigenposes, which constitute our reduced pose model. By optimizing the geodesics coordinates t_j given end-joints position constraints, we acheive fast, data-driven, full-body inverse kinematics (IK). Advantages are threefold:

- The optimization space is **much smaller** than for traditional IK, which both speeds up and ease the optimization.
- The optimization **inherently exploits correlations** between joints to reach constraints, resulting in a more natural pose.
- The geodesics formulation allows a quick computation of the jacobian used in the optimization.

The PGA-based IK is then used to recover frames given only end-joints constraints: that way we only store few global trajectories and constraint the extremities of the skeleton, where compression artifacts are usually the most noticeable (*e.g.* footskating). Moreover, this allows *easy* editing of compressed motions by only ajusting end-joints trajectories. In order to recover the original data using this IK algorithm, one will need:

- The inner orientations mean μ and the k leading principal geodesics $(v_j)_{j<k} \in T_1SO(3)^n \simeq \mathbb{R}^{3n}$
- The end-joints trajectories across time
- The root joint's orientation and position across time

For further data compression, we use the multiscale representation presented in [RDS*05] to compress both the root joint's orientation, and end-joints' trajectories. This method is suitable for data lying in Riemannian symmetric spaces, such as orientation and position data. It uses an iterated predict/correct step on subsamped data to build a pyramid of details. Prediction in our case is done using tangent space spline interpolation, and we acheive compression by simply omitting the highest levels of details. The whole compression pipeline is summarized on figure 2. If compressed end-joints global trajectories are smoothed more than wanted, one can always use entropy coding to store reconstruction errors with controllable additional overhead.

Sequence	Compr. ratio	Distortion rate	Decompr. time (msec/frame)	#frames	#geodesics
Walking, slow	1:182	5.1	31.2	6179	12
Various, fixed feet	1:118	7.1	18.9	5498	8
Breakdance	1:97	5.1	52	4499	15

Table 1: *Compression ratios obtained using our technique*

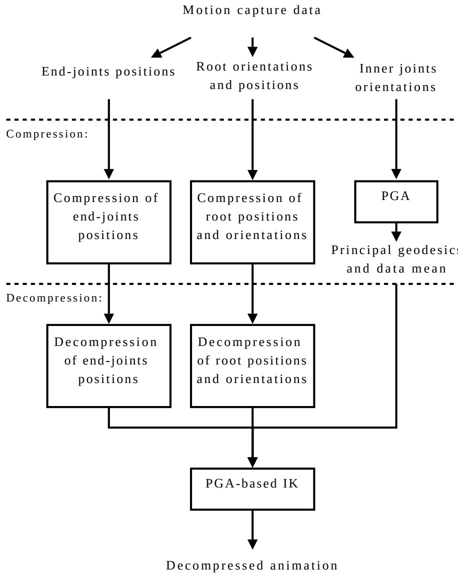

Figure 2: *Flow diagram for the compression pipeline*

3. Results and Conclusion

Though the lack of a robust, efficient metric to assess perceptual closeness of animations makes side-by-side comparisons difficult, table 1 shows that our approach allows very high compression ratios, with few distortion. The metric used here is similar to [LM06], $d = 100\frac{\|A-\tilde{A}\|}{\|A-E(A)\|}$, where A (resp. $\tilde{A}$) is the matrix of original (resp. compressed) global positions, and $E(A)$ is the mean positions matrix. The decompression time per frame scales with the number of geodesics used to represent the input poses. While this might not be fast enough for realtime video games applications, we believe that IK perfomances can be substentially improved, resulting in a powerful set of tools for both motion compression and editing.

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