RECOVERING ARTICULATED POSE OF 3D POINT CLOUDS

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Abstract

We present an efficient optimization method to determine the 3D pose of a human from a point cloud. The well-known ICP algorithm is adapted to fit a generic articulated template to the 3D points. Each iteration jointly refines the parameters for rigid alignment, uniform scale as well as all joint angles. In experimental results we demonstrate the effectiveness of this computationally efficient approach.

Keywords: *Motion Capture, 3D Registration, Articulated ICP.*

Introduction In recent years much work has been dedicated to motion capture. However, the majority depends on intensive manual initialization procedures and are prone to errors due to fast motion. Here, we address the problem of robustly fitting a generic articulated template to a 3D point cloud (from a single scan, visual hull, z-cams etc.) in terms of rigid alignment, uniform scaling and pose adaptation.

Preprocessing The input point cloud as well as the generic template consist of a 3D mesh, normalized to zero mean and unit variance. Additionally, the template vertices are grouped into body parts, which imply joints between them (16 body parts and 15 joints in our case). We manually pick a template from the data base with a similar pose. Any other method which does this automatically could be used instead, e.g. Shape Similarity Trees [2]. To bring the selected template and target into broad alignment the template's principle axes are aligned to the target point cloud. Rigid alignment in terms of uniform scale, rotation and translation is achieved by using Extended Orthogonal Procrustes Analysis [1].

Global Hierarchical Pose Alignment The algorithm is run in a hierarchical manner. The first iteration adapts the similarity parameters and the rotation matrices of the joints directly connected to the base body part. Following iterations add rotation parameters for further joints along the kinematic chains.

In order to map the template vertices as close as possible onto the target point cloud the Iterative Closest Point algorithm is modified to jointly adjust the joint angles besides refining the similarity transformation parameters (totaling in $p = 52$ adjustable parameters in our case, 6 rigid, 1 scale and 45 kinematic parameters). Thereby n correspondences are established: For each template vertex the closest target vertex, and also for each target vertex the closest template vertex is searched for. The objective function for minimization is modeled as sum of distances between all corresponding vertices. The template vertices $\mathbf{T}_i$ and corresponding target vertices $\mathbf{S}_i$ along each kinematic chain contribute distance costs according to the kineamtic chain equation (subscripts denote the number of joints from current to base body part):

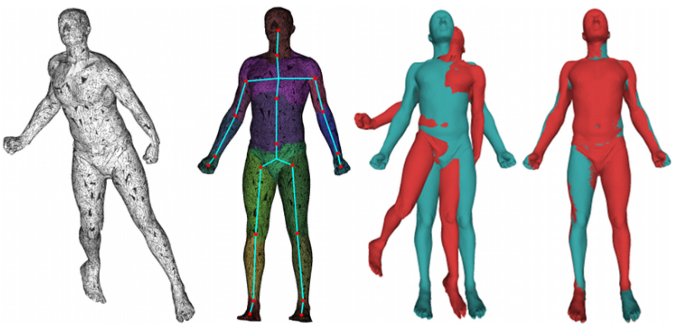
$$
\begin{aligned}
d_0 =& ||\mathbf{S}_0 - s\mathbf{R}\mathbf{T}_0 - \mathbf{t}\mathbf{1}^T||\\
d_1 =& ||\mathbf{S}_1 - \mathbf{R}_1(s\mathbf{R}\mathbf{T}_1 + (\mathbf{t}-\mathbf{t}_1)\mathbf{1}^T) - \mathbf{t}_1\mathbf{1}^T||\\
d_2 =& ||\mathbf{S}_2 - \mathbf{R}_2(\mathbf{R}_1(s\mathbf{R}\mathbf{T}_2 + (\mathbf{t}-\mathbf{t}_1)\mathbf{1}^T) + (\mathbf{t}_1-\mathbf{t}_2)\mathbf{1}^T) - \mathbf{t}_2\mathbf{1}^T||\\
& \dots
\end{aligned}
$$

with $\mathbf{1}$ being a n-vector of 1's, $\mathbf{R}$, $\mathbf{t}$, s being the similarity transformation parameters and $\mathbf{R}_1$, $\mathbf{R}_2$ being the 3×3-rotation matrices for the first and second joint with rotation centers $\mathbf{t}_1$ and $\mathbf{t}_2$. Using linear approximation of rotation matrices [4], the equation system can be rearranged to yield one common ICP update rule for all parameters of the form:

$$\Delta \left[s\ \mathbf{t}\ \mathbf{R}\ \mathbf{R_1}\ \mathbf{R_2}\ \dots\right]^T = (\mathbf{M}^T\mathbf{M})^{-1}(\mathbf{M}^T\mathbf{N})$$

with $\mathbf{M}$ being a $3n \times p$ matrix and $\mathbf{N}$ being a $3n$-vector, which can be setup and solved efficiently.

Experimental Results The presented method is evaluated on the SCAPE dataset [3]. Scans are artificially deformed and successfully fitted back to their non-deformed original. On average an initial mean distance of 0.13 is reduced to 0.00047.



Scan Template Initial Final

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