Personalization and Evaluation of a Real-time Depth-based Full Body Tracker
Supplemental Material

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I. Shape Eigenmatrix

We follow the approach of Hasler *et al.* presented in [1]. Here, the authors register a template mesh with P vertices into a point cloud using global and local mesh deformations. Given S laser-scans, let $\mathcal{M}_s \in \mathbb{R}^{3P}$, $s \in [1:S]$ be the stacked vertex positions of the fitted meshes. Now, we compute the average mesh

$$\overline{\mathcal{M}} = \frac{1}{S}\sum_{s=1}^{S}\mathcal{M}_s. \tag{1}$$

Note that $\overline{\mathcal{M}}$ corresponds to $\mathcal{M}_{0,\boldsymbol{\chi}_0}$ in Sect. 3.1 of the paper. Then, we compute the auto correlation matrix

$$\mathcal{C} = \frac{1}{S}\sum_{s=1}^{S}(\mathcal{M}_s - \overline{\mathcal{M}})(\mathcal{M}_s - \overline{\mathcal{M}})^T. \tag{2}$$

Let Φ_s, $s \in [1:S]$ be the eigenvectors of C, sorted from most significant to least significant. A suitable eigenvector-matrix is now defined as

$$\Phi = [\Phi_1 \cdots \Phi_R], \tag{3}$$

with $R \leq S$. The corresponding shape parameter vector is denoted as $\boldsymbol{\varphi} \in \mathbb{R}^R$.

II. Analytic Derivatives

Let $\boldsymbol{\varphi}$, $\boldsymbol{\chi}$, $\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}}$, $\mathcal{N}_{\boldsymbol{\varphi},\boldsymbol{\chi}}$, and Φ be defined as described in Sect. 3.1 of the paper. Furthermore, let $\Phi_{\boldsymbol{\chi}_0}(p,i) \in \mathbb{R}^{3\times 1}$ be the sub-matrix of Φ that influences the p-th vertex of $\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}}$ and is multiplied with the i-th shape parameter $\boldsymbol{\varphi}_i$ in $\boldsymbol{\varphi}$. Now, we define $\Theta_{\boldsymbol{\chi}}(p)[\cdot]$ to be the linear blend skinning transformation of vertex p, so that

$$\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}}(p) = \Theta_{\boldsymbol{\chi}}(p)[\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}_0}(p)], \tag{4}$$

$$\mathcal{N}_{\boldsymbol{\varphi},\boldsymbol{\chi}}(p) = \Theta_{\boldsymbol{\chi}}(p)[\mathcal{N}_{\boldsymbol{\varphi},\boldsymbol{\chi}_0}(p)], \text{ and} \tag{5}$$

$$\Phi_{\boldsymbol{\chi}}(p,i) = \Theta_{\boldsymbol{\chi}}(p)[\Phi_{\boldsymbol{\chi}_0}(p,i)], \tag{6}$$

with $p \in [1:P]$ and $i \in [1:|\boldsymbol{\varphi}|]$. Note that $\Theta_{\boldsymbol{\chi}}(p)[\cdot]$ does not apply a translational offset to directional vectors such as $\mathcal{N}_{\boldsymbol{\varphi},\boldsymbol{\chi}_0}(p)$ or displacement vectors such as $\Phi_{\boldsymbol{\chi}_0}(p,i)$ but only to positional vectors such as $\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}_0}(p)$.

Now, let $M(p)$, $T(q)$, and $N(p)$ be defined as in Sect. 3.2 of the paper. The partial derivatives of the distance functions d_{point} and d_{normal} with respect to the i-th shape parameter $\boldsymbol{\varphi}_i$ are defined as

$$\frac{\partial d_{\text{point}}(p,q)}{\partial \boldsymbol{\varphi}_i} = 2\langle M(p) - T(q), \Phi_{\boldsymbol{\chi}}(p,i)\rangle, \text{ and} \tag{7}$$

$$\frac{\partial d_{\text{normal}}(p,q)}{\partial \boldsymbol{\varphi}_i} = 2\langle M(p) - T(q), N(p)\rangle \cdot \langle \Phi_{\boldsymbol{\chi}}(p,i), N(p)\rangle. \tag{8}$$

Analogously, the partial derivative with respect to $\boldsymbol{\chi}$ are

$$\frac{\partial d_{\text{point}}(p,q)}{\partial \boldsymbol{\chi}} = 2\langle M(p) - T(q), \mathcal{M}'_{\boldsymbol{\varphi},\boldsymbol{\chi}}(p)\rangle, \text{ and} \tag{9}$$

$$\frac{\partial d_{\text{normal}}(p,q)}{\partial \boldsymbol{\chi}} = 2\langle M(p) - T(q), N(p)\rangle \cdot \langle \mathcal{M}'_{\boldsymbol{\varphi},\boldsymbol{\chi}}(p), N(p)\rangle, \text{ with} \tag{10}$$

$$\mathcal{M}'_{\boldsymbol{\varphi},\boldsymbol{\chi}}(p) = \Theta'_{\boldsymbol{\chi}}(p)[\mathcal{M}_{\boldsymbol{\varphi},\boldsymbol{\chi}_0}(p)], \text{ and} \tag{11}$$

$$\Theta'_{\boldsymbol{\chi}}(p) = \frac{\partial \Theta_{\boldsymbol{\chi}}(p)}{\partial \boldsymbol{\chi}}. \tag{12}$$

The calculation of the partial derivative $\Theta'_{\boldsymbol{\chi}}(p)$ highly depends on how $\Theta_{\boldsymbol{\chi}}(p)$ is represented. A good explanation for twist-based representations of $\Theta_{\boldsymbol{\chi}}(p)$—as used in our implementation—can be found, *e. g.*, in Murray *et al.* [2], Chapter 4.

References

[1] N. Hasler, C. Stoll, M. Sunkel, B. Rosenhahn, and H.-P. Seidel, "A statistical model of human pose and body shape," *CGF*, vol. 28, no. 2, 2009.

[2] R. M. Murray, Z. Li, and S. S. Sastry, *A Mathematical Introduction to Robotic Manipulation.* CRC Press, 1994.