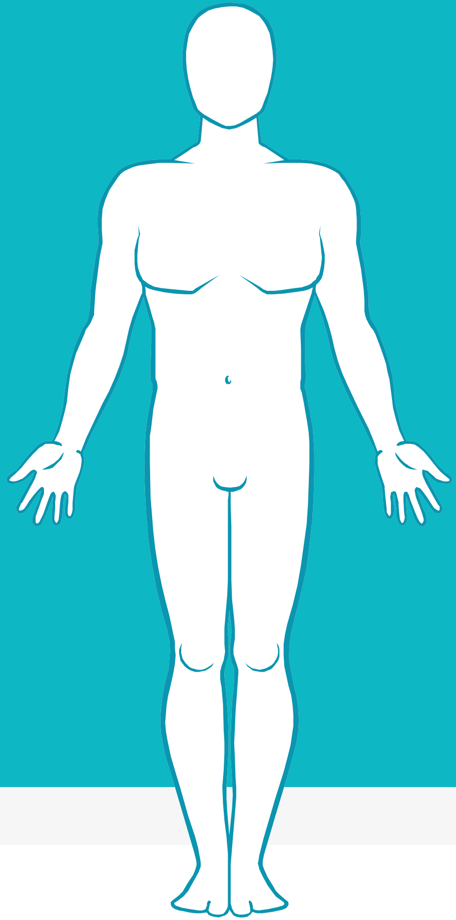
IEEE ICIP 2021

Multi-View Human Model Fitting Using Bone Orientation and Joints Triangulation



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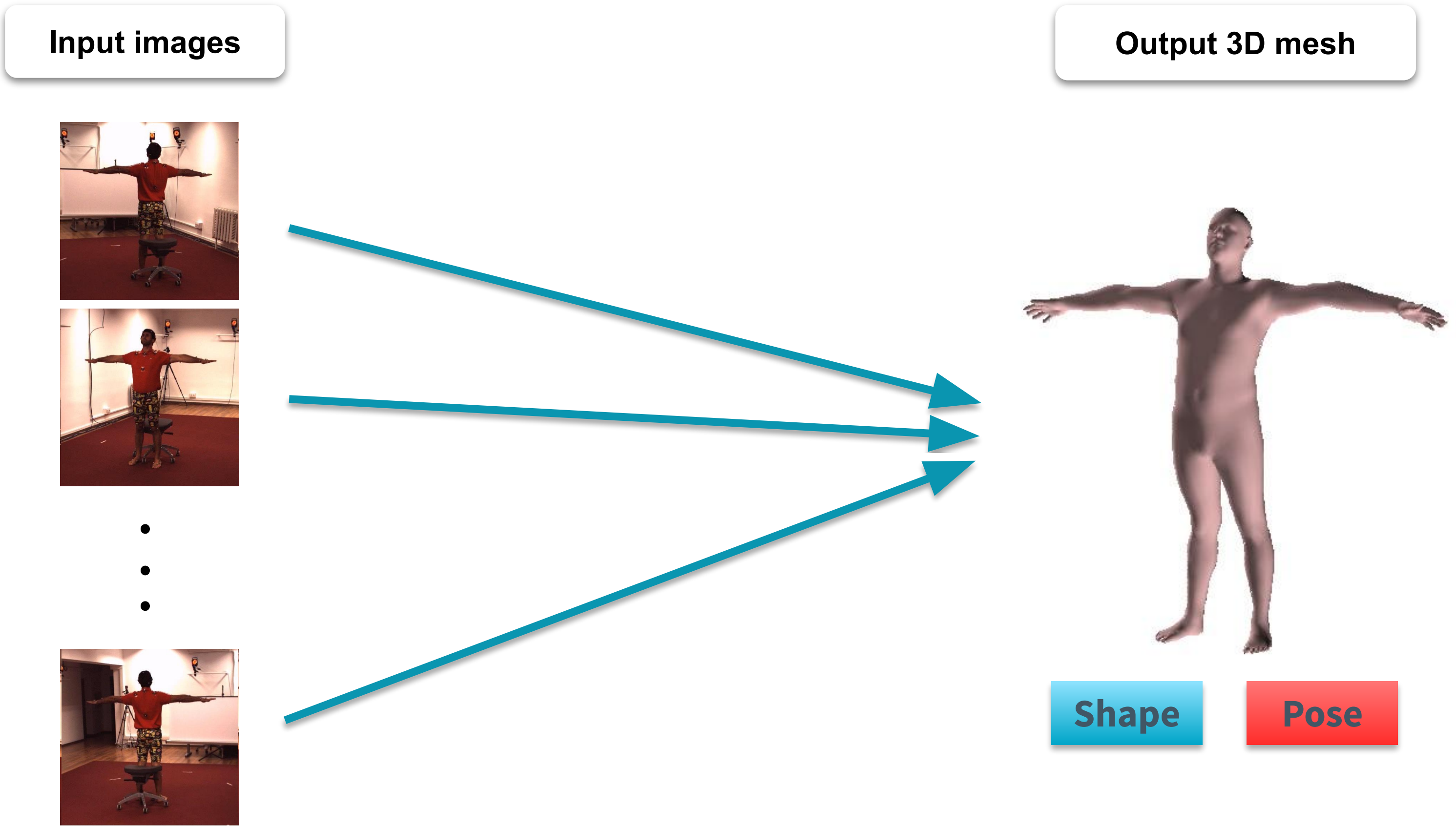
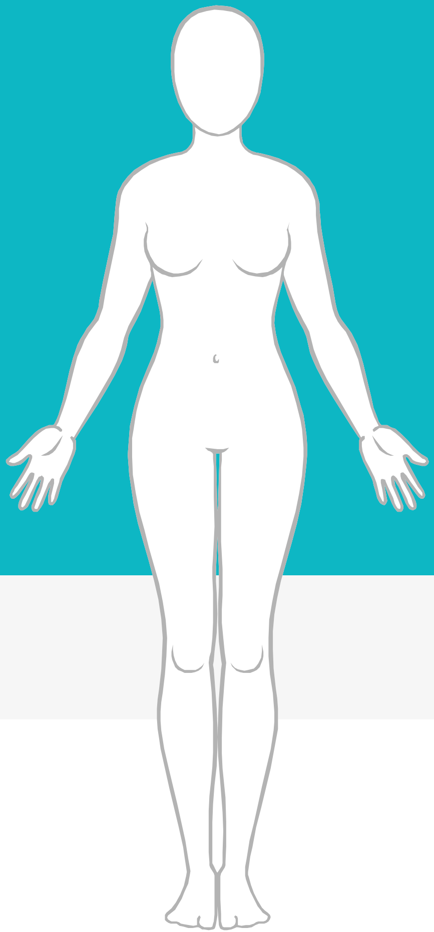
ÉTS

Le génie pour l'industrie

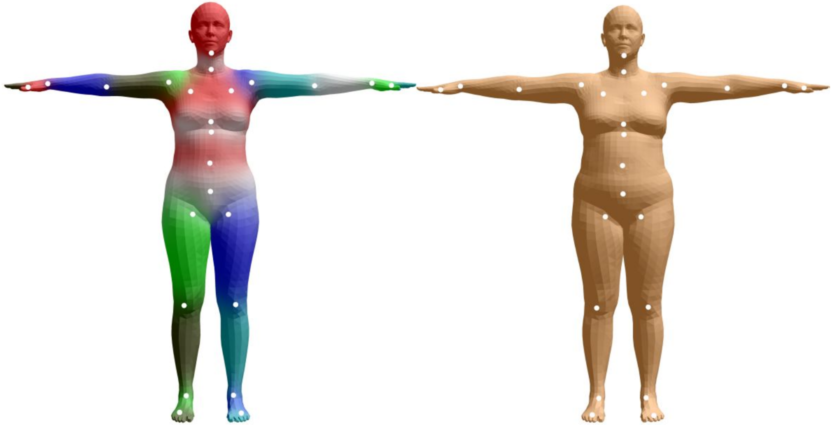
Problem Statement



1.
Related Work



SMPL - Loper and al. (2015)



$\bar{\mathbf{T}}, \mathcal{W}$ $\quad$ $\bar{\mathbf{T}} + B_S(\vec{\beta}),\ J(\vec{\beta})$

Start

Shape

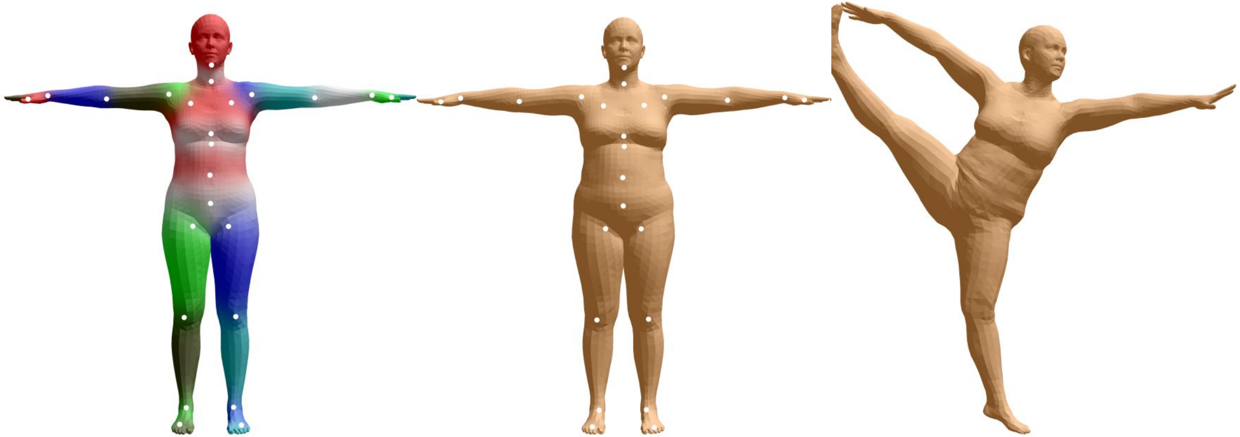
Shape β

PCA

CAESAR database

J : joints regressor - joints as a function of the body shape

SMPL - Loper and al. (2015)



$\bar{\mathbf{T}}, \mathcal{W}$

$\bar{\mathbf{T}} + B_S(\vec{\beta}),\ J(\vec{\beta})$

$W(T_P(\vec{\beta},\vec{\theta}), J(\vec{\beta}), \vec{\theta}, \mathcal{W})$

Start

Shape

Blend skinning

Pose $\boldsymbol{\theta}$

Axis-angles

SMPL - Take Away

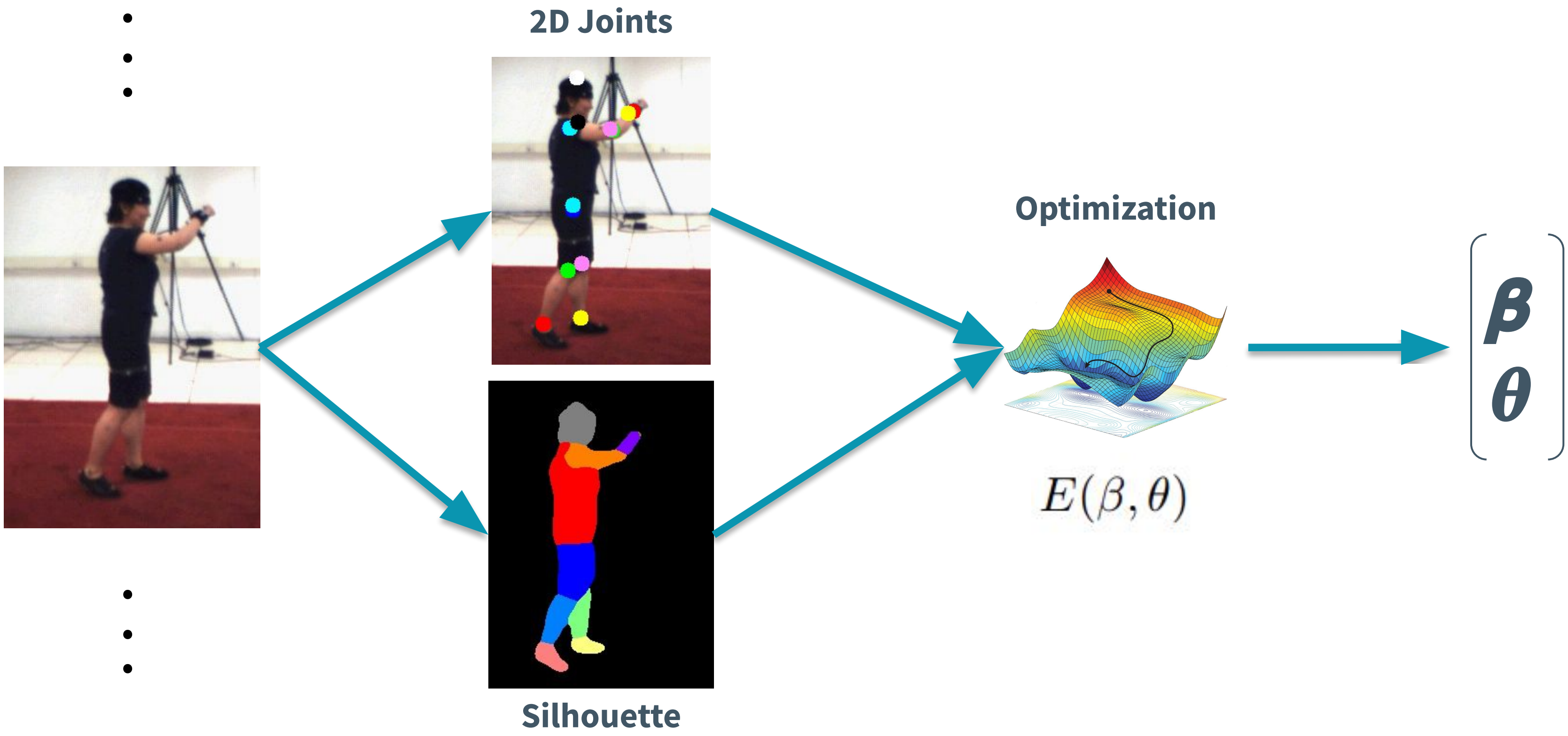
(d) $W(T_P(\vec{\beta},\vec{\theta}), J(\vec{\beta}), \vec{\theta}, \mathcal{W})$

Blend skinning

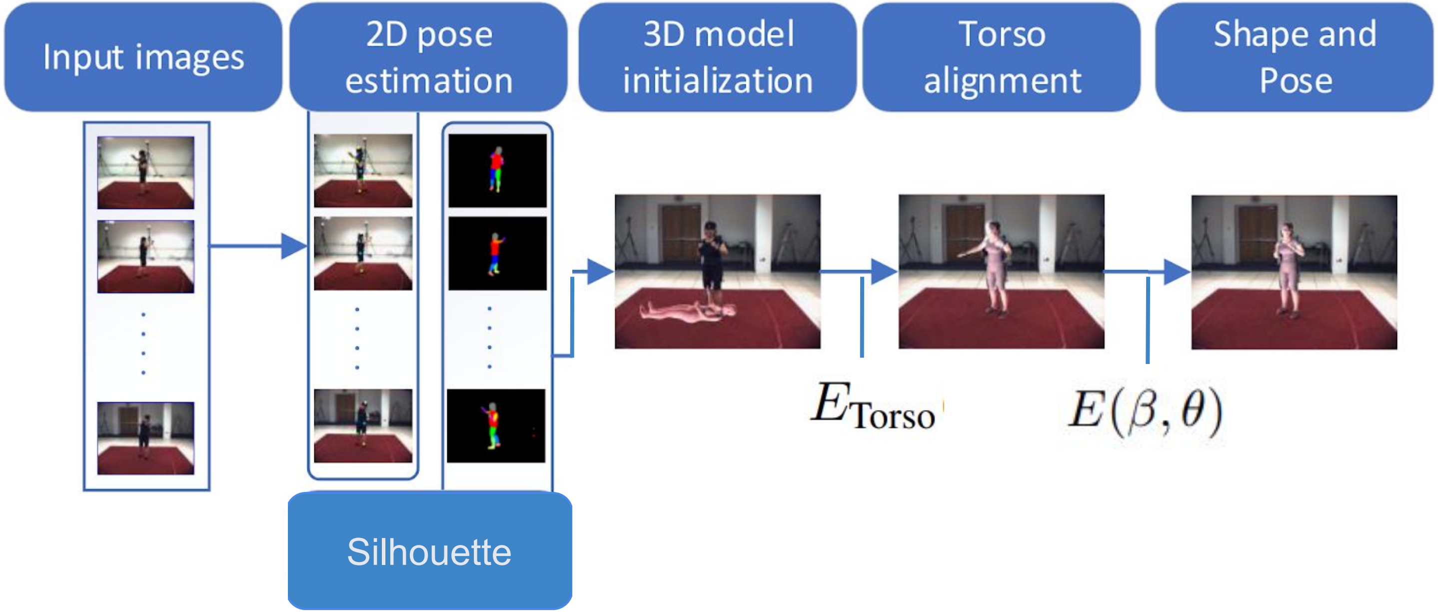
- **2 parameters** to be specified by users (shape $\boldsymbol{\beta}$ and pose $\boldsymbol{\theta}$)
- **PCA** and **optimization** to learn implicit parameters

Differentiable!

MuVS - Huang et al. (2017)



MuVS - Overview



MuVS - Objective Function

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta};K_v,J^v_{\text{est}}) + E_S(\boldsymbol{\beta},\boldsymbol{\theta};K_v,U_v)$$

MuVS - Objective Function

pose prior

$$E(\beta,\theta) = \lambda_\theta \boxed{E_\theta(\theta)} + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, J_{\text{est}}^v) + E_S(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, U_v)$$

To favor probable poses and penalize improbable ones

Learned from a Mocap dataset

MuVS - Objective Function

pose prior **shape prior**

$$E(\beta,\theta) = \lambda_\theta \boxed{E_\theta(\theta)} + \lambda_\beta \boxed{E_\beta(\beta)} + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta};K_v,J_{\text{est}}^v) + E_S(\boldsymbol{\beta},\boldsymbol{\theta};K_v,U_v)$$

To favor probable shapes and penalize less probable ones

Built from SMPL's PCA

MuVS - Objective Function

pose prior   shape prior

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, J^v_{\text{est}}) + E_S(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, U_v)$$

projected joints error

K_v : view #v camera parameters (intrinsic & extrinsic)

J^v_{est} : view #v estimated 2D joints

MuVS - Objective Function

pose prior shape prior

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta};K_v,J_{\text{est}}^v) + E_S(\boldsymbol{\beta},\boldsymbol{\theta};K_v,U_v)$$

projected joints error

silhouette error

U_v: view #v estimated silhouette

MuVS - Optimization & Issues

pose prior shape prior

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta};K_v,J^v_{\text{est}}) + E_S(\boldsymbol{\beta},\boldsymbol{\theta};K_v,U_v)$$

projected joints error silhouette error

Complex optimization

Local optimums

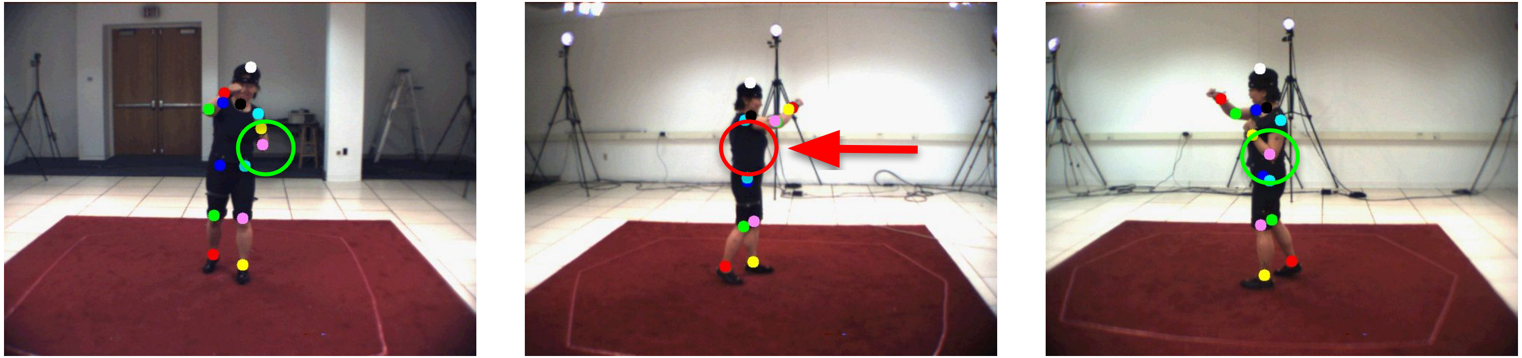
Initialisation matters

MuVS - Optimization & Issues

pose prior　　shape prior

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, J^v_{\text{est}}) + E_S(\boldsymbol{\beta},\boldsymbol{\theta}; K_v, U_v)$$

projected joints error　　silhouette error

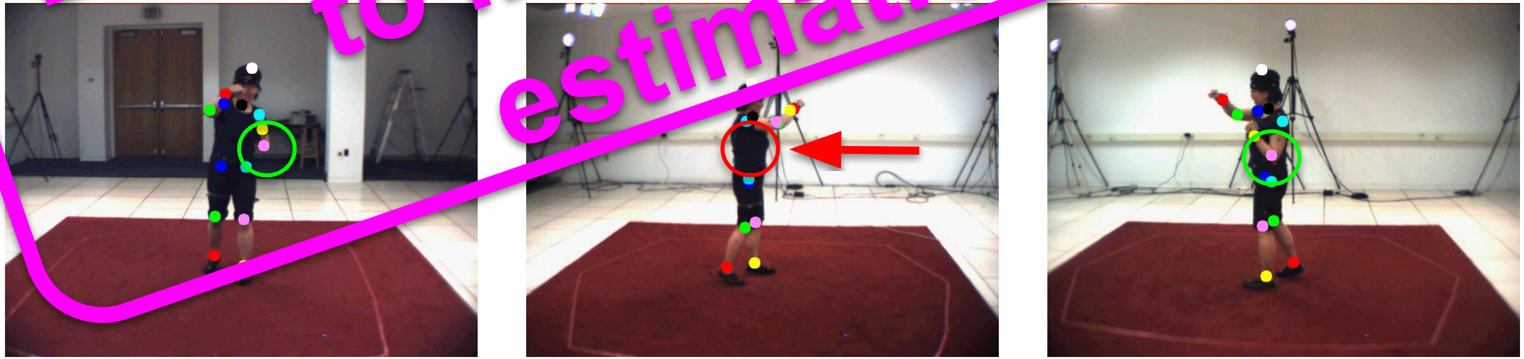


MuVS - Optimization & Issues

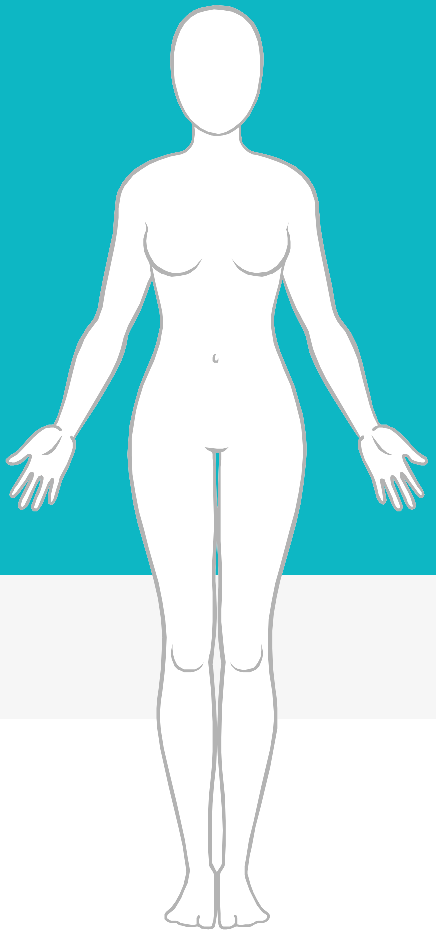
pose prior | shape prior | projected joints error | silhouette error

$$E(\beta,\theta) = \lambda_\theta E_\theta(\theta) + \lambda_\beta E_\beta(\beta) + \sum_{v=1}^{V} E_J(\boldsymbol{\beta},\boldsymbol{\theta};K_v,J^v_{est}) + E_S(\boldsymbol{\beta},\boldsymbol{\theta};K_v,U_v)$$

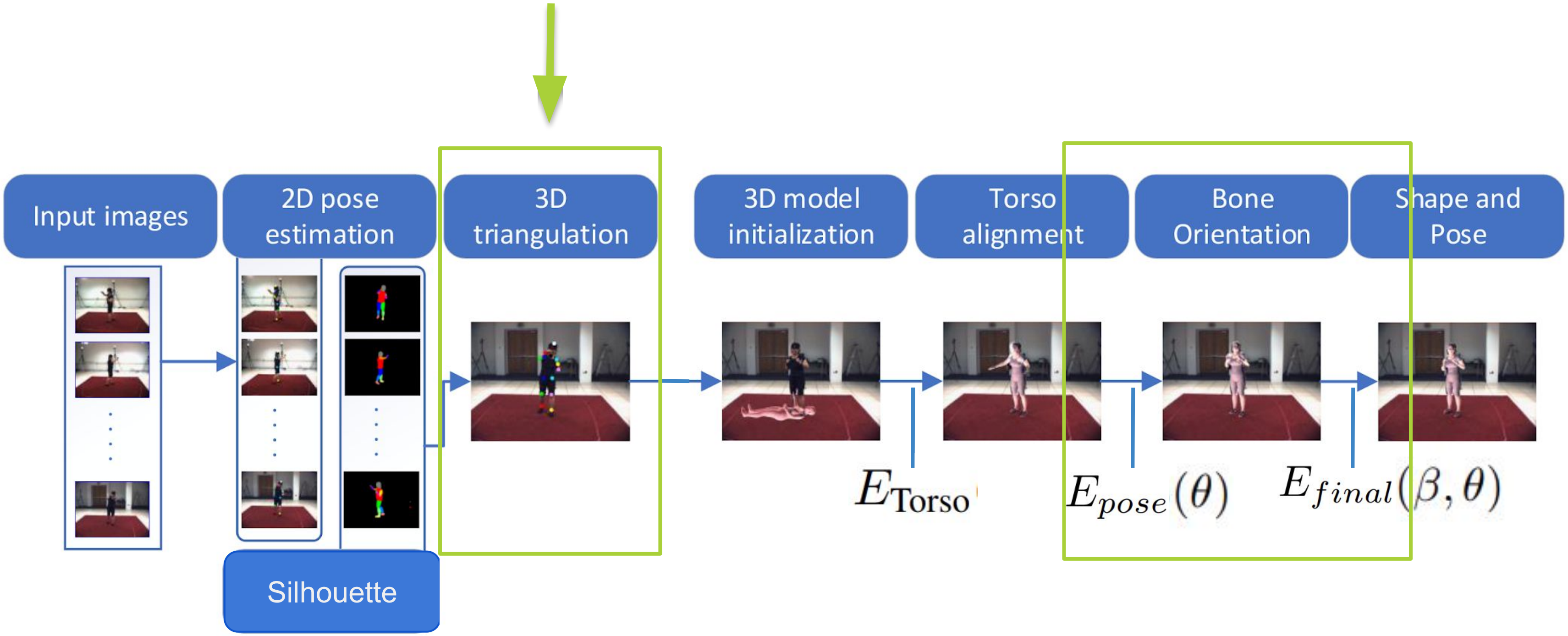
Energy function sensitive to incorrect joint estimations



2.
Our Approach



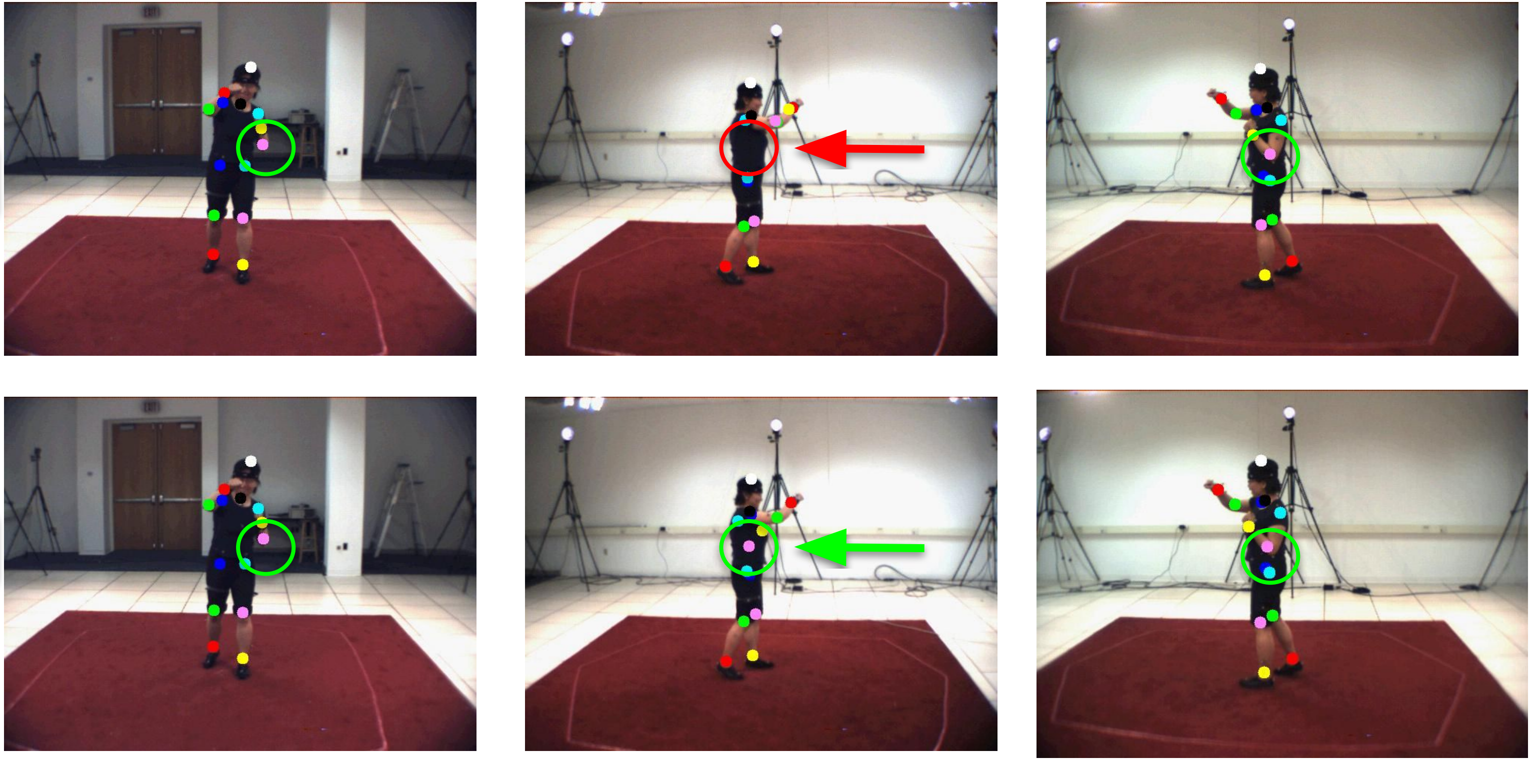
Ours – Overview



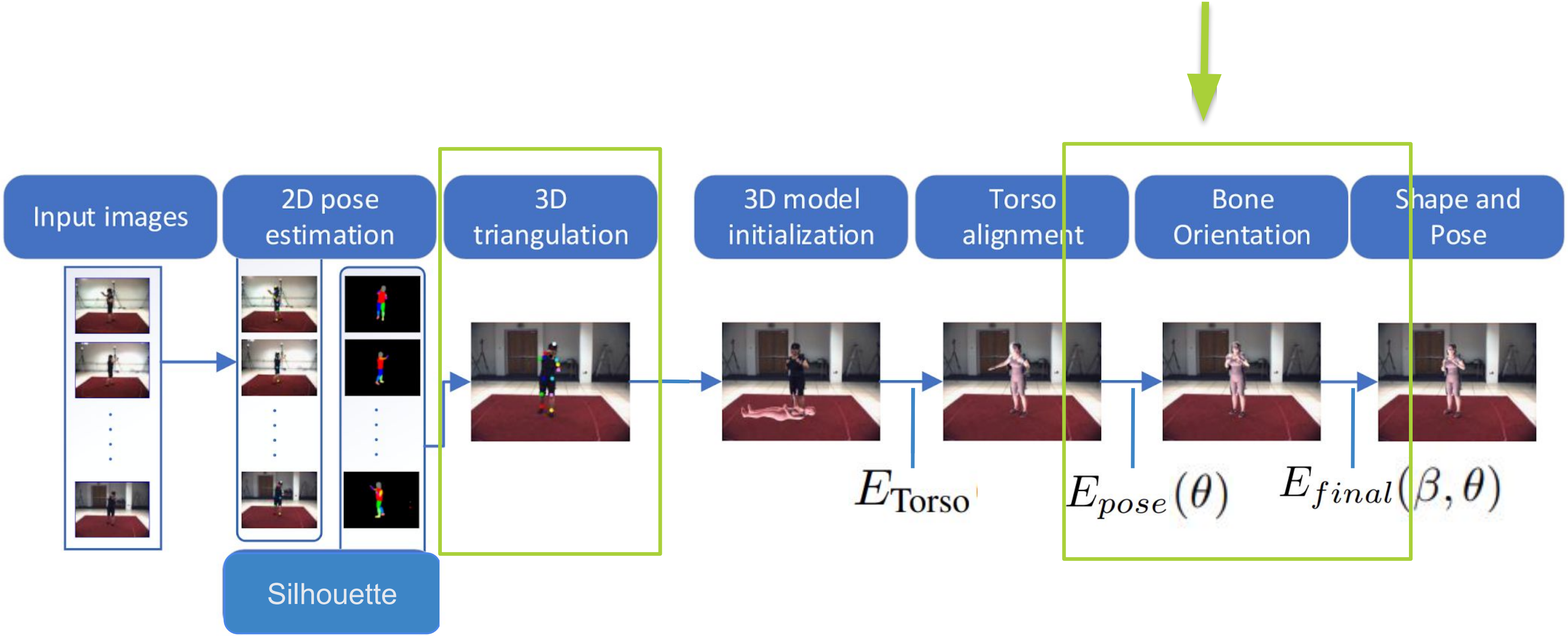
3D Pose Triangulation (Iskakov et al. (2019))

Before

After



Ours – Overview



Ours – Bone Orientation

SMPL joints (3D)

$$E_{pose}(\vec{\theta}) = \lambda_\theta E_\theta(\vec{\theta}) + \lambda_{bone} \sum_{b \in B} ||\Phi(J(\vec{\beta}, \vec{\theta}), b) - \Phi(J_{3D}, b)||_2^2$$

Triangulated joints

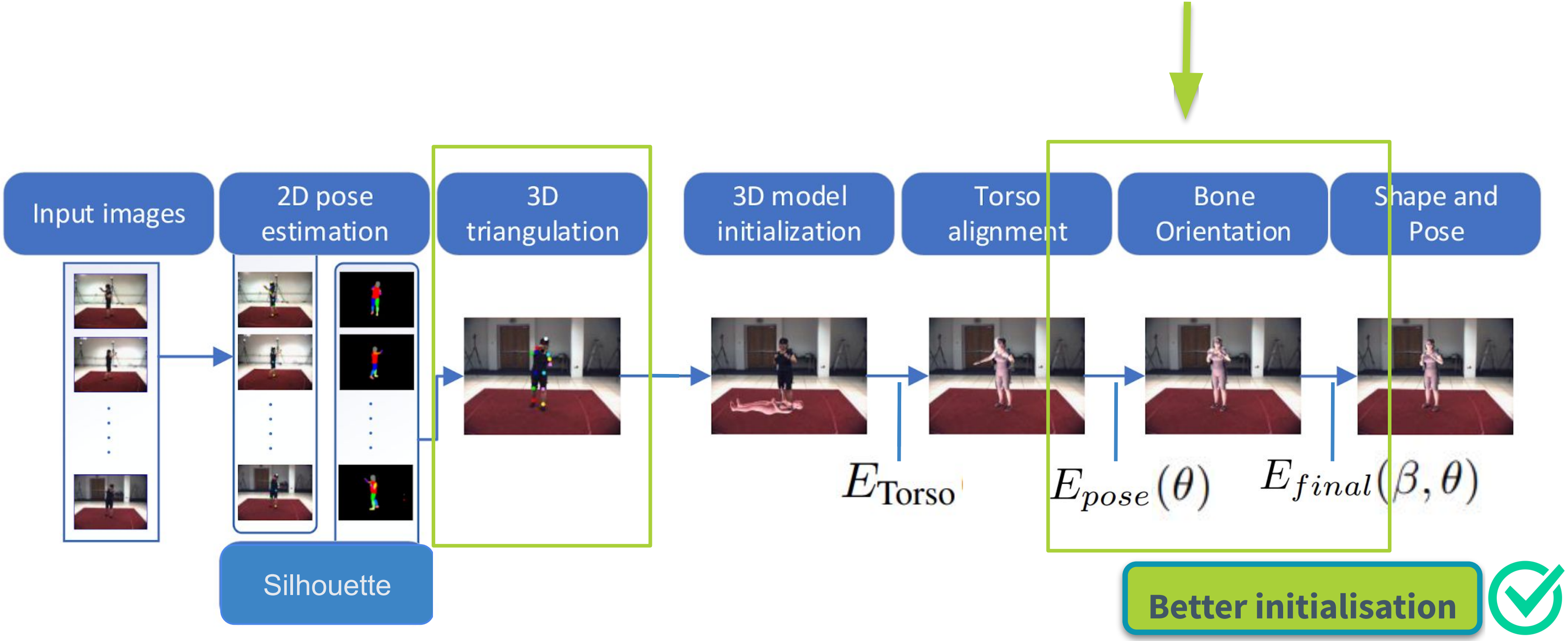
B: Set of all bones

L2 normalization

$$\Phi(J, b) = \frac{J_{child(b)} - J_{parent(b)}}{||J_{child(b)} - J_{parent(b)}||_2}$$

Decouple pose vs shape

Ours – Overview



Ours - Shape & Pose

SMPL joints (3D)

shape prior

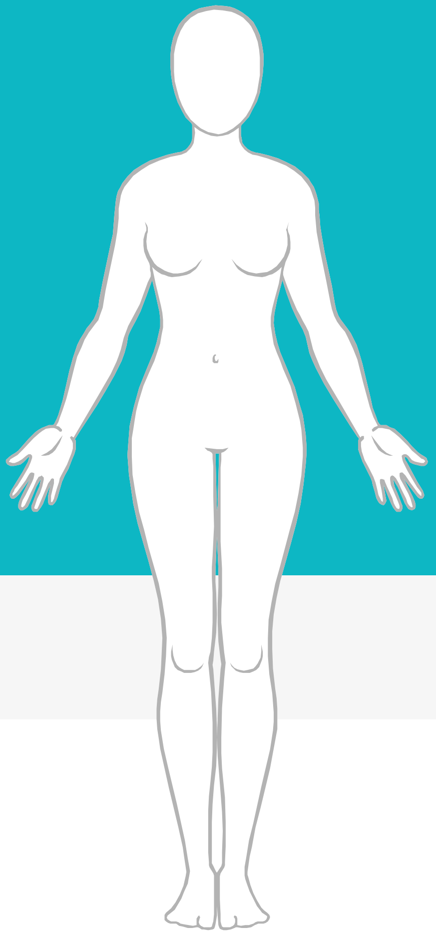
$$E_{\text{final}}(\vec{\beta}, \vec{\theta}, \vec{\gamma}) = \lambda_\theta E_\theta(\vec{\theta}) + \lambda_\beta E_\beta(\vec{\beta}) + \lambda_J ||J_{3D} - J(\vec{\beta}, \vec{\theta}) + \vec{\gamma}||_2^2$$

pose prior

joint error

Triangulated joints

3.
Evaluation and Discussion

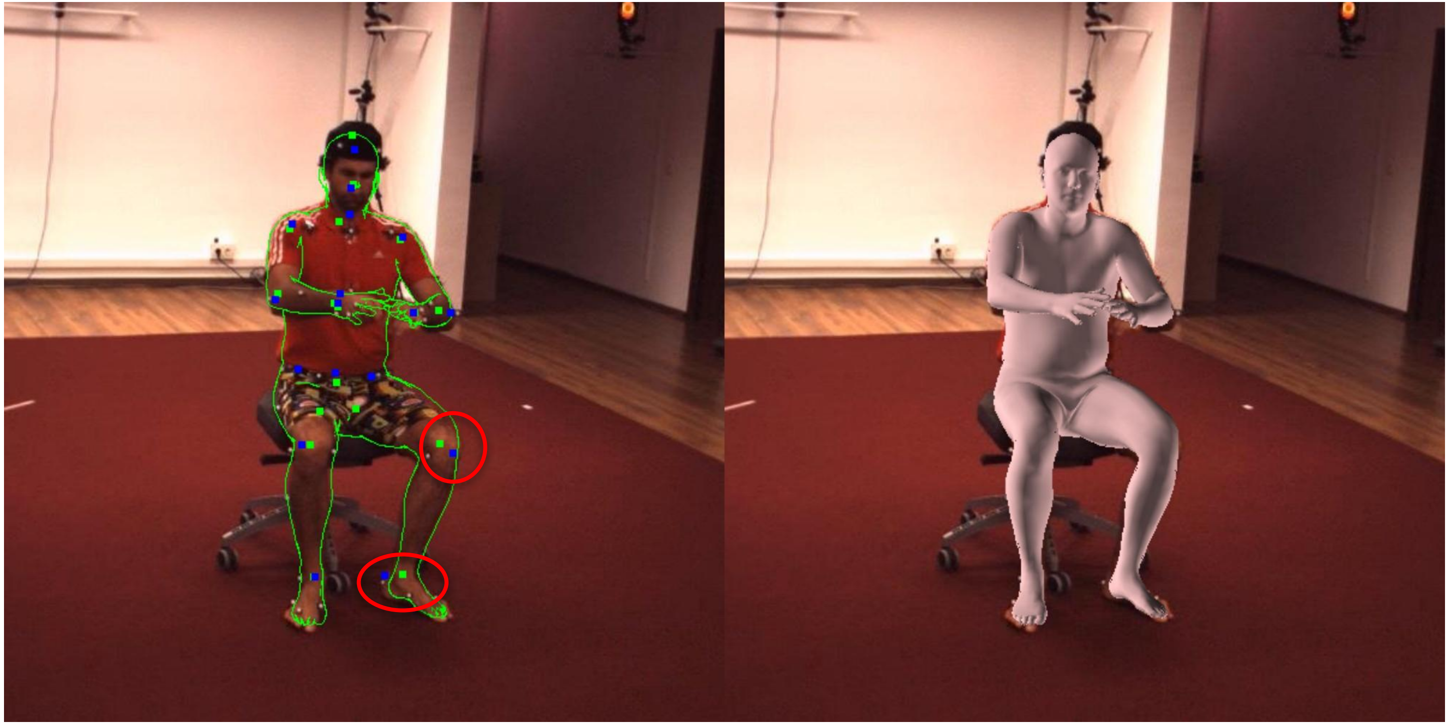


Joints – SMPL vs. Human3.6M

Large shift in position between the two models

Human3.6M

SMPL



Evaluation on Human3.6M

S: Silhouettes

T: Temporal

SV: Shift vectors

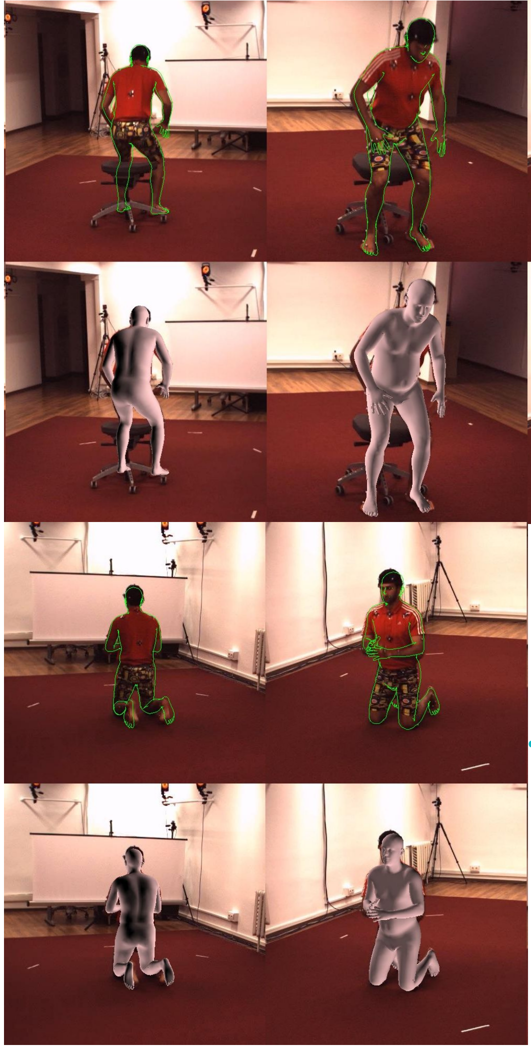
BOC: Bone orientation step

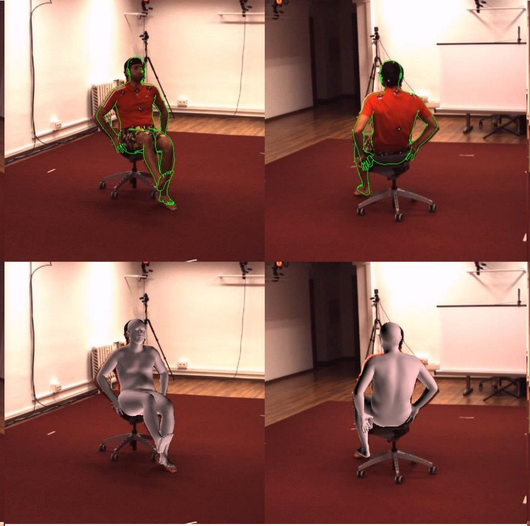
Mean Per Joint Position Error (mm)

Method	Shape	PA	MV	MPJPE
Kanazawa *et al.* (2018)	Yes	Yes	No	66.65
Trumble *et al.* (2018)	No	No	Yes	62.50
Kolotouros *et al.* (2019a)	Yes	Yes	No	62.00
Pavlakos *et al.* (2017b)	No	No	Yes	56.89
$\text{MuVS}^{\text{S, T}}$	Yes	Yes	Yes	47.09
Ours	Yes	Yes	Yes	54.86
Ours^{SV}	Yes	Yes	Yes	39.56
Ours^{BOC}	Yes	Yes	Yes	46.37
$\text{Ours}^{\text{BOC, SV, S}}$	Yes	Yes	Yes	33.07
$\text{Ours}^{\text{BOC, SV}}$	Yes	Yes	Yes	30.13
Iskakov *et al.* (2019)	No	Yes	Yes	20.80
He *et al.* (2020)	No	Yes	Yes	19.00

Conclusion

- A bone orientation constraint (BOC) to recover the pose parameter independently from the shape parameter;
- A more precise initialization for the simultaneous optimization of pose and shape parameters thanks to the BOC;
- A two-step optimization process that improves the accuracy of the pose and shape estimations.
- Shift vectors





THANK YOU!