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AJAHR : Amputated Joint Aware 3D Human Mesh Recovery

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Abstract

Existing human mesh recovery methods assume a standard body structure, overlooking conditions like limb loss and suffering from a lack of relevant datasets. We propose Amputated Joint Aware 3D Human Mesh Recovery (AJAHR), an adaptive framework that jointly trains a mesh recovery network with a body-part amputation classifier. We also introduce Amputee 3D (A3D), a synthetic dataset of diverse amputee poses. Our method maintains competitive non-amputee performance while achieving state-of-the-art results for amputees.

Introduction

✔ Problems

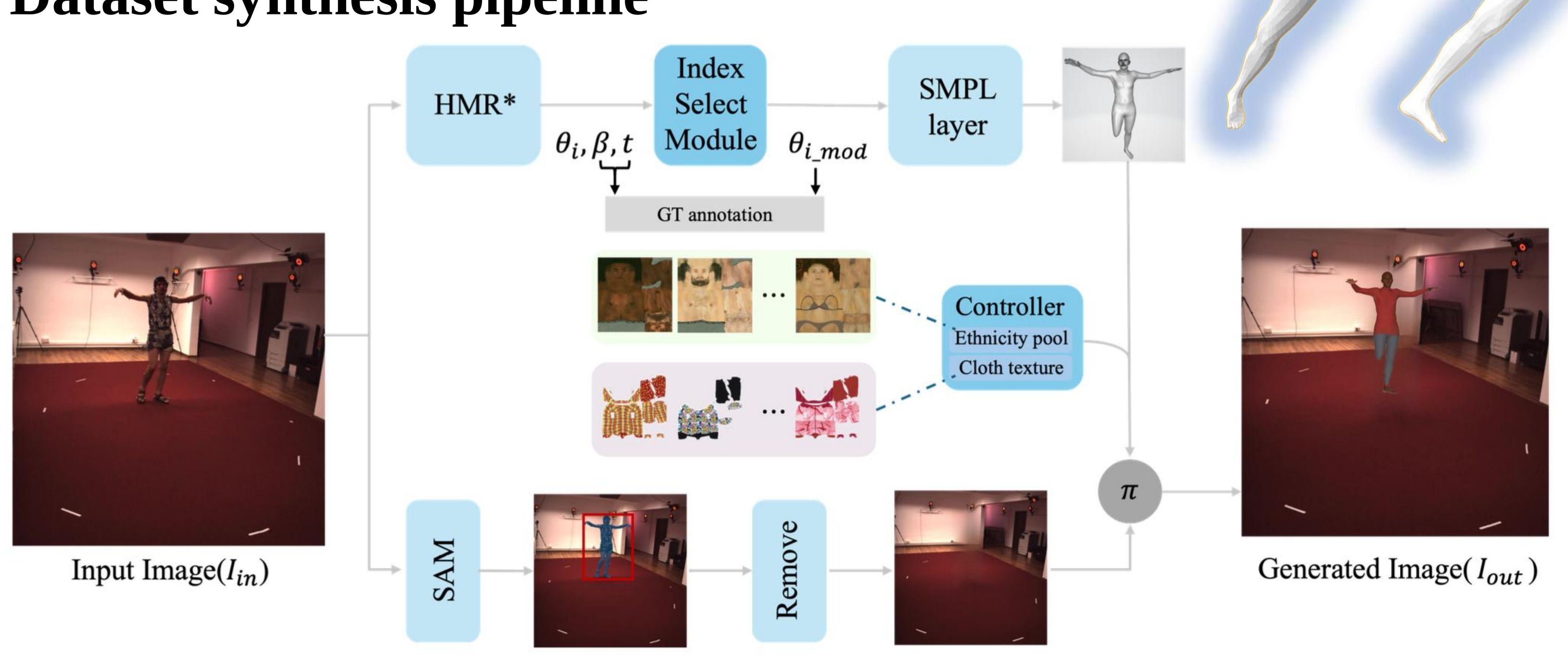
(1) No prior work on Human Mesh Recovery (HMR) for individuals with limb loss.
(2) HMR models trained only on non-amputee data, leading them to misrepresent amputated limbs by hallucinating unrealistic body parts.
(3) Collecting real amputee data is very challenging.

✔ How to Solve?

(1) Developed synthetic dataset **A3D** and real-world evaluation set **ITW-amputee.**
(2) **AJAHR** detects **amputation** status and performs tailored mesh recovery, ensuring competitiveness on **non-amputees** while achieving SOTA on amputee datasets

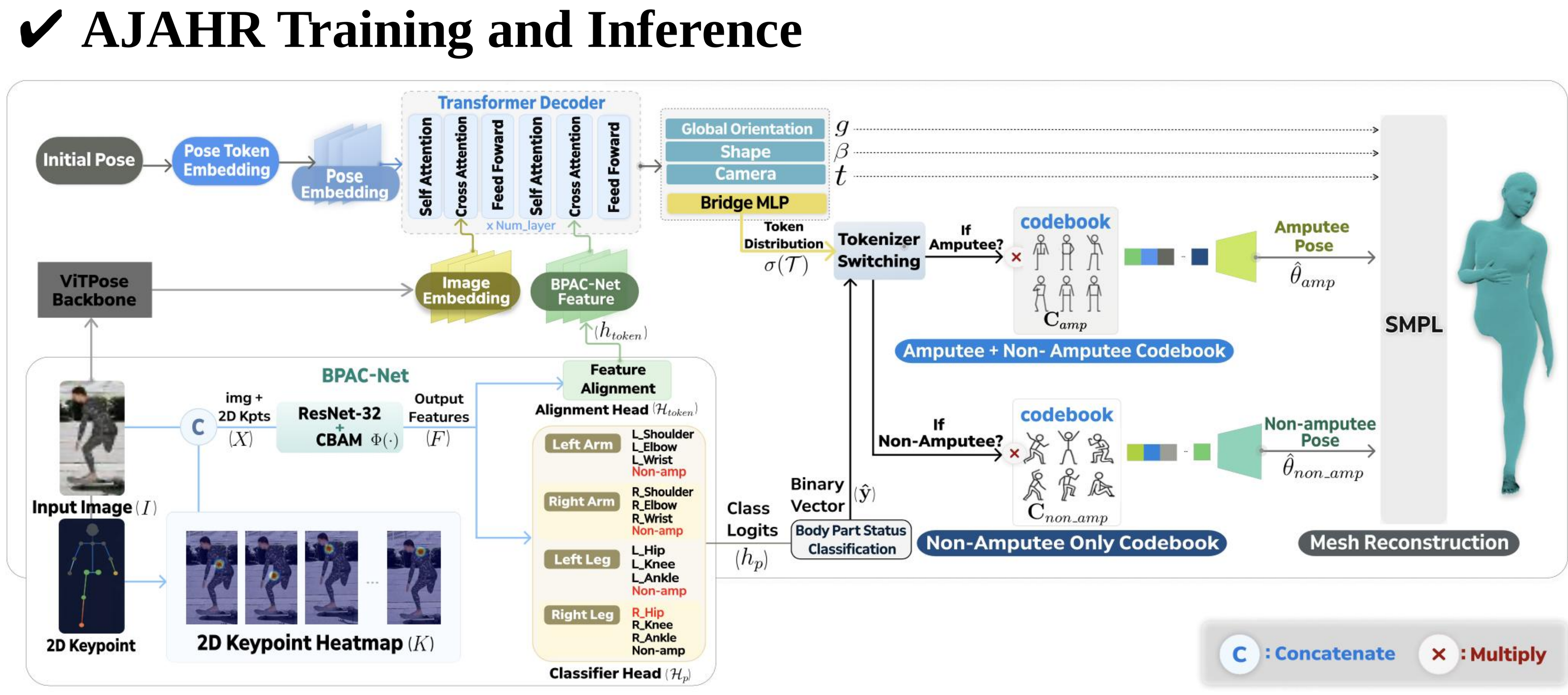
Methods & Materials

✔ Dataset synthesis pipeline



- **Input** : Benchmark dataset (e. g., H36M[1])
- **Off-the-shelf-model** : ScoreHMR[2]
- **Amputation types** : 12 SMPL joint index types (0–11, body limbs), zeroing amputated & connected joints (follwing kinematic tree)

✔ AJAHR Training and Inference



- VQ-VAE-based pretrained tokenizers for amputee and non-amputee pose encoding
- BPAC-Net: Predicting limb amputation from images and 2D keypoints
- AJAHR restores SMPL parameters using a TokenHMR[3]-based model under the guidance of BPAC-Net's amputation status.

$$\mathcal{L}_{overall} = \underbrace{\lambda_\theta \mathcal{L}_\theta(\boldsymbol{\theta}, \hat{\boldsymbol{\theta}})}_{Pose} + \underbrace{\lambda_\beta \mathcal{L}_\beta(\boldsymbol{\beta}, \hat{\boldsymbol{\beta}})}_{Shape} + \underbrace{\lambda_{3D} \mathcal{L}_{3D}(\mathbf{J}_{3D}, \hat{\mathbf{J}}_{3D})}_{3D\ Kpts} + \underbrace{\lambda_{2D} \mathcal{L}_{2D}(\mathbf{J}_{2D}, \hat{\mathbf{J}}_{2D})}_{2D\ Kpts} + \underbrace{\lambda_{cls} \mathcal{L}_{cls}}_{BPAC\text{-}Net}$$

Results

✔ Quantitative Result

Method	A3D			ITW-amputee		
	MVE↓	MPJPE↓	PA-MPJPE↓	MVE↓	MPJPE↓	PA-MPJPE↓
HMR2.0 [10]	89.35	96.75	86.14	**110.33**	154.43	121.83
BEDLAM-CLIFF [5, 24]	83.38	88.12	56.45	128.09	150.12	117.74
TokenHMR [9]	76.01	74.70	49.94	136.52	146.12	91.00
AJAHR (Ours)	**73.42**	**73.19**	**49.42**	116.42	**129.25**	**77.18**

Table 2. **Results on Amputee Data.**

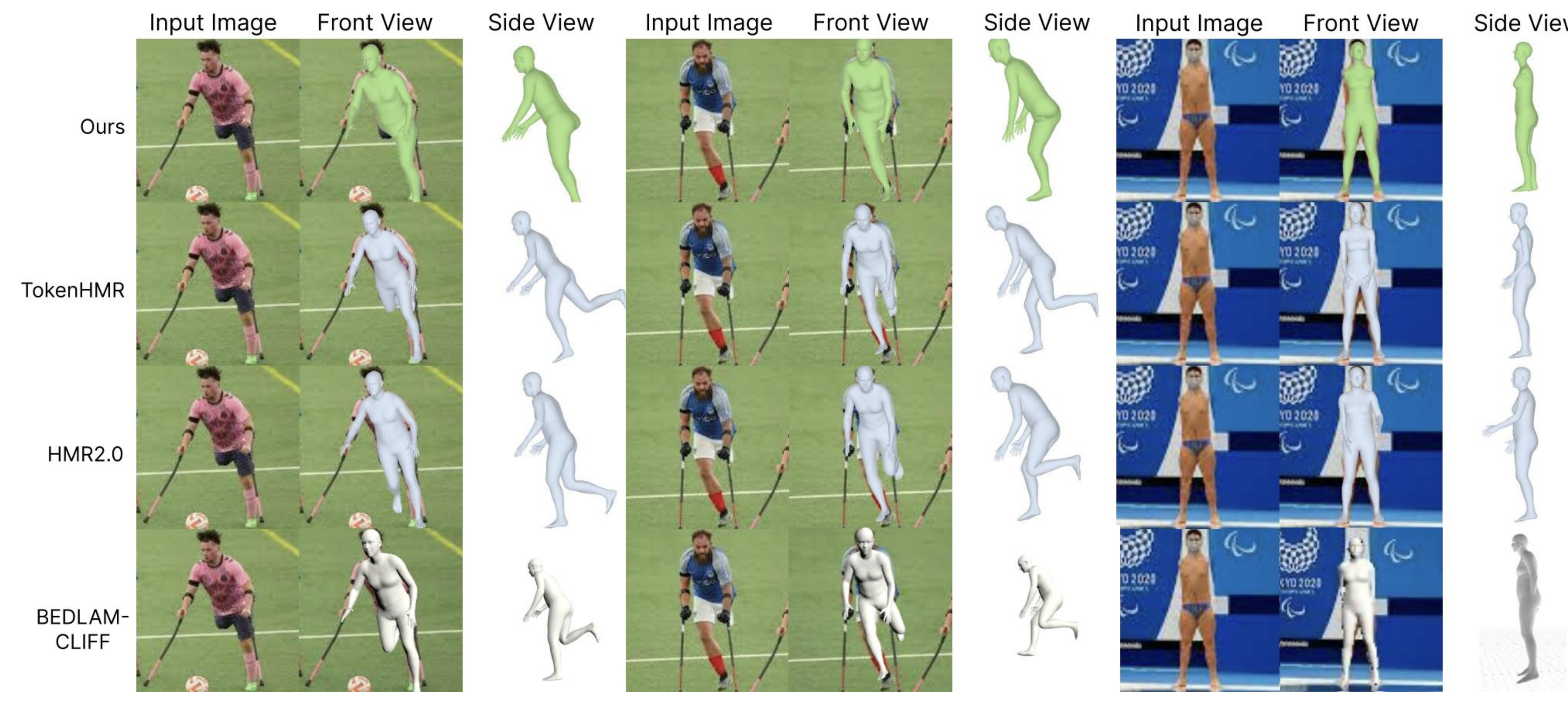
Method	EMDB [20]			3DPW [41]		
	MVE↓	MPJPE↓	PA-MPJPE↓	MVE↓	MPJPE↓	PA-MPJPE↓
HMR2.0 [10]	141.41	117.66	75.89	95.29	81.64	53.95
BEDLAM-CLIFF [5, 24]	129.00	97.88	62.40	99.32	76.45	51.21
TokenHMR [9]	113.26	93.77	58.98	**90.23**	72.87	47.17
AJAHR (Ours)	**112.83**	**91.74**	**58.62**	95.26	**71.77**	**44.94**

Table 3. **Results on Non-Amputee Data.**

Protocol of Metric : For fair evaluation, GT amputation labels are used to remove corresponding mesh parts; in inference, amputation status comes from a 2D keypoint detector.
Model Inclusivity : AJAHR performs well for both amputee and non-amputee meshes, with BPAC-Net accurately distinguishing occlusion from amputation.

Method	A3D (amputation)				3DOH50K [45] (occlusion)			
	Accuracy↑	Precision↑	Recall↑	F1↑	Accuracy↑	Precision↑	Recall↑	F1↑
Ours	0.881	0.756	0.922	0.820	0.956	0.956	1.000	0.977

✔ Qualitative Result



Conclusions & Future work

- We propose AJAHR, which includes a synthetic dataset pipeline for individuals with limb loss and a model that classifies amputation status and recovers meshes for both amputees and non-amputees via tokenizer switching.
- Currently, AJAHR supports only joint-level amputations and excludes prosthetics; future work will extend it to prosthetics and irregular amputations, enabling broader applications in sports analysis and inclusive AR/VR.

References

[1] Ionescu, Catalin, et al. "Human3. 6m: Large scale datasets and predictive methods for 3d human sensing in natural environments." TPAMI. 2013
[2] Stathopoulos, Anastasis, Ligong Han, and Dimitris Metaxas. "Score-guided diffusion for 3d human recovery." CVPR. 2024.
[3] Dwivedi, Sai Kumar, et al. "Tokenhmr: Advancing human mesh recovery with a tokenized pose representation." CVPR. 2024.

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