# AJAHR : Amputated Joint Aware 3D Human Mesh Recovery


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Project Page

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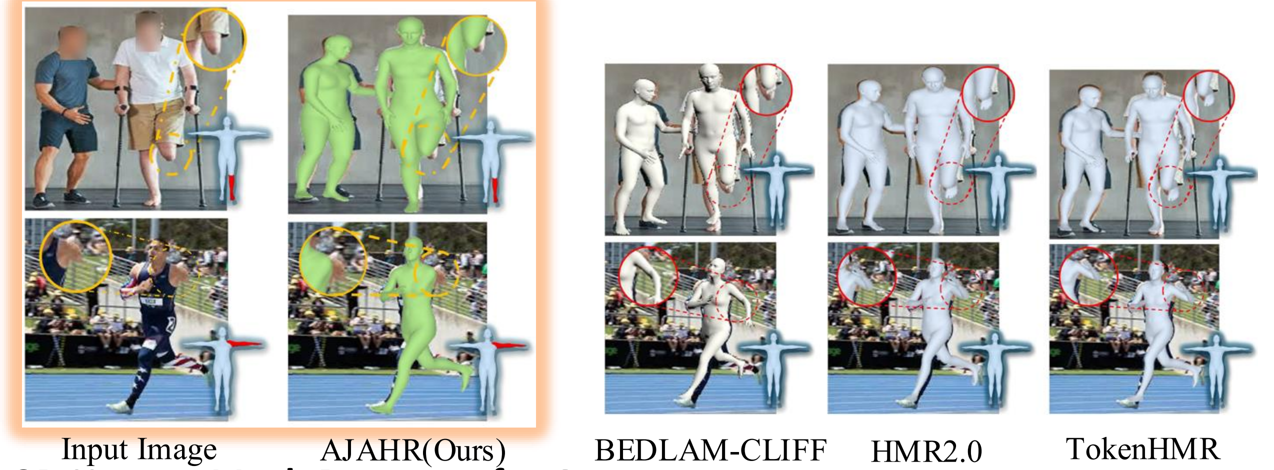
## Introduction & Motivation



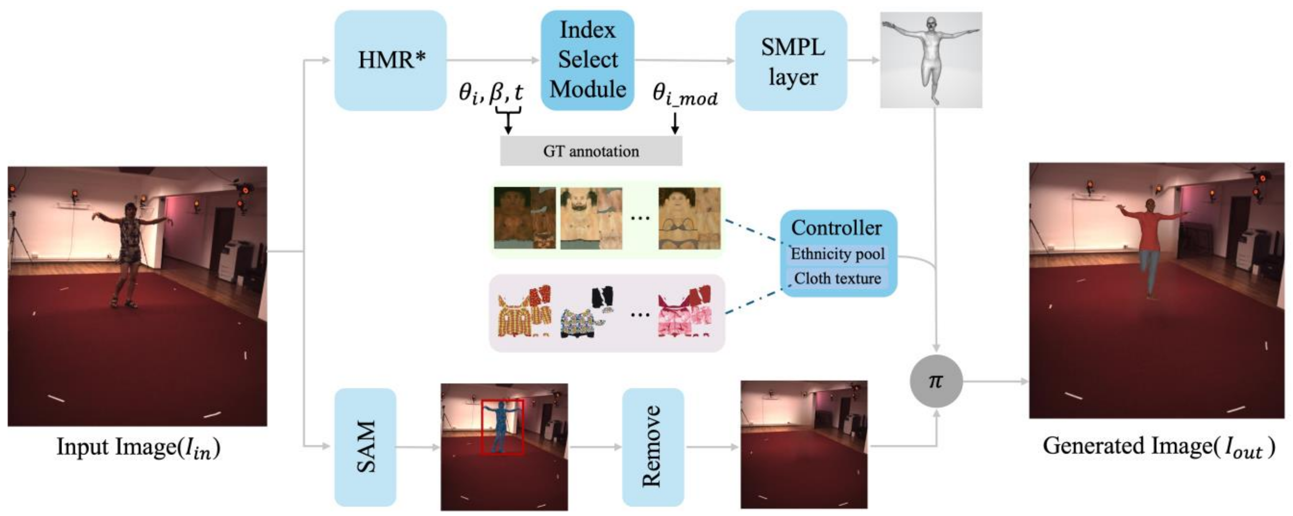

### 3D Human Mesh Recovery for Amputees

- No prior Human Mesh Recovery (HMR) Studies addressing amputees
- Existing HMR models trained only on non-amputee data
  → Previous HMR models hallucinate missing limbs
- Collecting real amputee data is very challenging

## Contribution

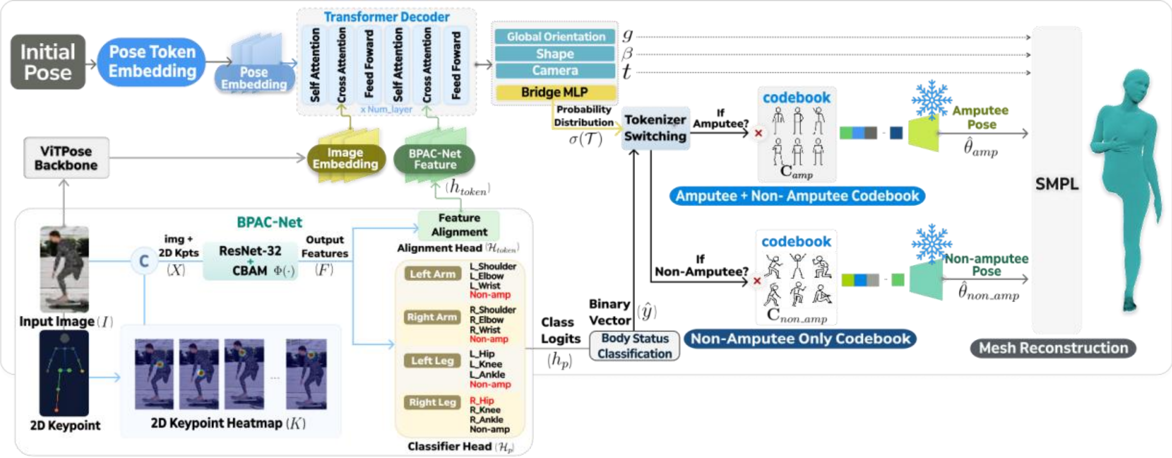
- We introduce an amputation-aware HMR framework that detects whether a subject is **amputee or non-amputee from a single view and reconstructs the corresponding mesh.**
- We introduce **amputee datasets** : A3D (synthetic) and ITW-amputee (in-the-wild crawling evaluation dataset)
- We propose **BPAC-Net** for amputation localization and AJAHR-Tokenizer for model switching, forming a unified framework that restores SMPL by dispatching to amputee-specific vs intact-specific reconstruction experts.
- Our approach demonstrates **state-of-the-art performance in amputee** datasets while maintaining **competitiveness on non-amputee** benchmarks

## Dataset Pipeline



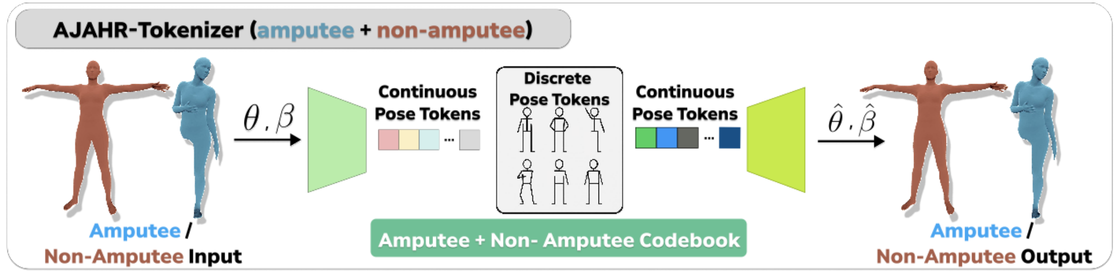

## Model Architecture

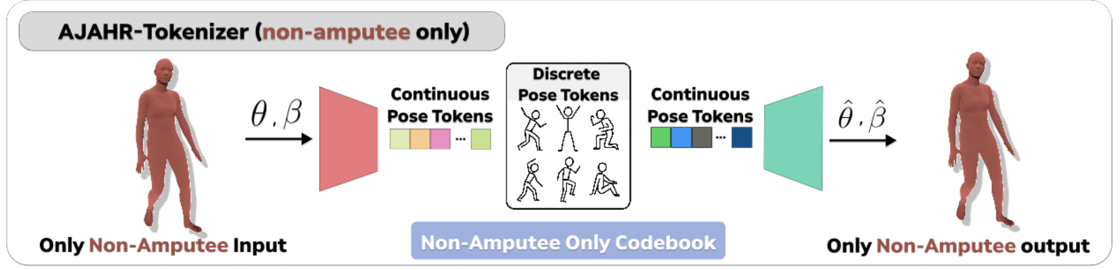
### - Framework of AJAHR




- **BPAC-Net** : Predicts amputation and a mesh representation from the **image + 2D keypoints**, implicitly guiding AJAHR with spatial cues
- **AJAHR** : Uses TokenHMR-Based regression outputs; **switches tokenizer per BPAC-Net to recover pose**, predicting remaining SMPL parameter with Linear Layer

### - AJAHR-Tokenizer




- **After training** : **Freeze** codebook & decoder parameters, switch by Amputation status to reconstruct poses **(no update in AJAHR)**

## Conclusion

— Prior HMR hallucinates missing limbs; not amputation-aware.
— Amputation-aware HMR with BPAC-Net + AJAHR-Tokenizer
— Ethical synthetic pipeline (A3D); in-the-wild eval (ITW-Amputee).
— Strong on amputees; competitive on benchmarks, robust in the wild.

## Quantitative Result

### Evaluation Protocol

※ For fair evaluation, we **remove the corresponding mesh parts** using ground-truth (GT) amputation labels. During inference, 2D keypoints obtained from a **keypoint detector** are fed into BPAC-Net to predict whether amputation is present.

### Amputee / Non-Amputee Dataset

| 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, 22] | 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 [18] | | | 3DPW [37] | | |
|---|---|---|---|---|---|---|
| | 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, 22] | 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.**

### BPAC-Net Accuracy

| Method | A3D (amputation) | | | | 3DOH50K [46] (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 |

### Dataset Quality

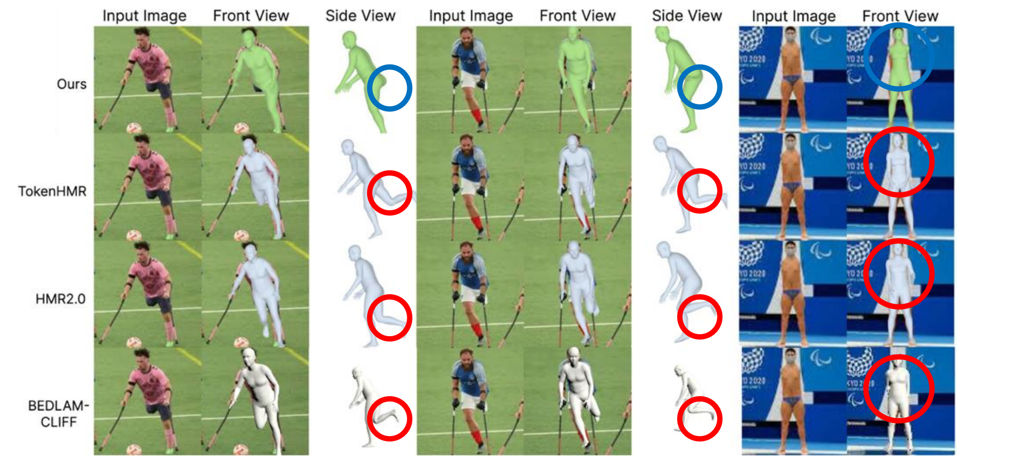
| Dataset | A3D(MPII [1]) | A3D(MSCOCO [11]) | A3D(H3.6M [6]) | Avg. |
|---|---|---|---|---|
| LPIPS [26],↓ | 0.0735 | 0.0421 | 0.16186 | 0.155 |

## Dataset

A3D

ITW-Amputee

## Qualitative Results on in-the-wild image




## Ablation Study

### Ablation Experiments on the Components of BPAC-Net and AJAHR-Tokenizer

| Experiments | Use Classifier | EMDB [20] | | | 3DPW [41] | | | A3D | | | ITW-amputee | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MVE↓ | MPJPE↓ | PA-MPJPE↓ | MVE↓ | MPJPE↓ | PA-MPJPE↓ | MVE↓ | MPJPE↓ | PA-MPJPE↓ | MVE↓ | MPJPE↓ | PA-MPJPE↓ |
| (a) Noise Ratio : 100% | ✓ | 117.71 | 96.22 | 60.97 | 99.03 | 75.64 | 49.31 | 91.30 | 91.21 | 71.31 | 144.08 | 147.41 | 88.08 |
| Noise Ratio : 75% | ✓ | 115.77 | 94.78 | 59.31 | 97.91 | 73.31 | 46.88 | 89.12 | 89.32 | 69.74 | 142.21 | 145.99 | 86.51 |
| Noise Ratio : 50% | ✓ | 115.31 | 94.12 | 59.22 | 97.43 | 72.77 | 45.87 | 88.76 | 88.98 | 69.32 | 141.78 | 145.01 | 86.17 |
| Noise Ratio : 25% | ✓ | 114.82 | 94.03 | 58.88 | 97.31 | 72.08 | 45.08 | 87.98 | 88.37 | 68.71 | 140.09 | 144.24 | 85.21 |
| (b) Image only | ✓ | 131.81 | 109.98 | 74.21 | 113.71 | 87.09 | 59.54 | 105.88 | 103.12 | 85.44 | 152.21 | 154.55 | 92.71 |
| Keypoint only | ✓ | 118.21 | 96.12 | 61.71 | 100.87 | 74.87 | 46.91 | 90.12 | 89.21 | 70.77 | 141.64 | 146.21 | 87.88 |
| (c) HMR2.0 [10] + BPAC-Net | ✓ | 149.31 | 125.69 | 80.74 | 100.21 | 89.74 | 56.91 | 104.72 | 104.75 | 94.32 | 134.71 | 176.46 | 132.27 |
| BEDLAM-CLIFF [5, 24] + BPAC-Net | ✓ | 133.75 | 100.29 | 73.24 | 103.98 | 83.21 | 54.28 | 92.77 | 96.48 | 75.87 | 147.51 | 166.07 | 126.90 |
| (d) 160 Tokens | ✓ | 117.38 | 98.12 | 61.94 | 101.56 | 75.83 | 47.21 | 90.47 | 90.28 | 71.04 | 144.78 | 147.91 | 89.63 |
| 640 Tokens | ✓ | 127.92 | 107.43 | 64.75 | 106.67 | 77.69 | 50.36 | 93.81 | 96.92 | 75.08 | 149.35 | 151.80 | 94.12 |
| **Ours** (Image + Keypoint guide + 320 Tokens) | ✓ | **114.52** | **93.73** | **58.01** | **97.02** | **71.97** | **44.98** | **87.11** | **87.91** | **68.01** | **139.64** | **143.74** | **84.91** |
| (e) Amputation Only (Single) | | 115.70 | 93.75 | 59.08 | 96.32 | 72.76 | 45.92 | 74.71 | 74.51 | 49.93 | 118.09 | 131.12 | 78.08 |
| Non Amputation Only (Single) | | 113.09 | 92.07 | 57.97 | 95.34 | 72.02 | 45.02 | 76.01 | 76.31 | 50.99 | 120.81 | 134.71 | 81.82 |
| **Ours (Unified)** | | **112.83** | **91.74** | **58.62** | **95.26** | **71.77** | **44.94** | **73.42** | **73.19** | **49.42** | **116.42** | **129.25** | **77.18** |

**(a) Add Noise to 2D kpts (b) BPAC-Net Input, (c) Change Backbone (d) AJAHR-Tokenizer Tokens (e) Dual Vs. Single Tokenizer**

## Acknowledgement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