# Zolly: Zoom Focal Length Correctly for Perspective-Distorted Human Mesh Reconstruction


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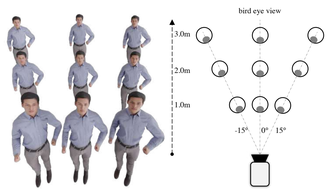
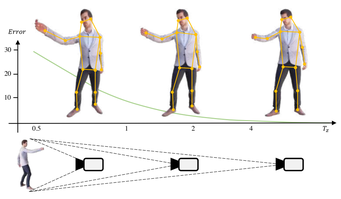
## Introduction

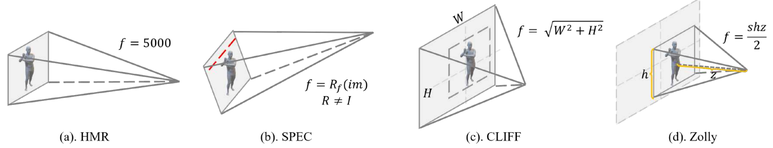
- **Motivation:** Existing 3D human mesh reconstruction methods use a constant $f$ or estimate one based on the background context. Such $f$ deviates a lot from distorted images caused by perspective projection.
  The distortion is directly caused by the distance and the facing angle to the camera center.
  Close-view shots could cause distortion on human bodies, which could be used to calculate the $f$.




- **Contribution**
  A novel camera system for the perspective-distorted 3DHMR task.
  A new neural model, and a hybrid re-projection loss.
  A new and the first synthetic dataset, PDHuman, for perspective-distorted 3D human pose estimation.

## Camera System Design




(a). HMR (b). SPEC (c). CLIFF (d). Zolly

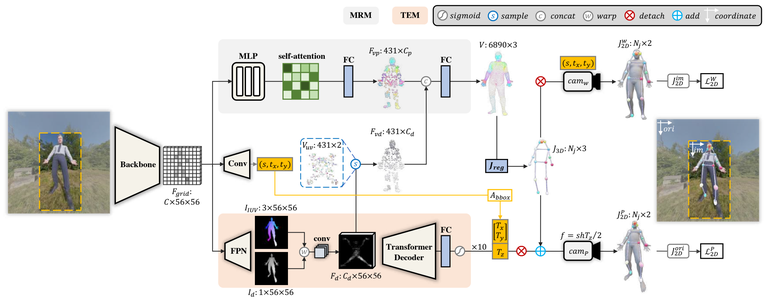
- **HMR**. $f = 5000$. Most methods follow this setting.
- **SPEC**. The $f$ is estimated by a network pre-trained on other datasets.
- **CLIFF**. Use the diagonal length as $f$ if no ground truth $f$.
- **Zolly**. $f = shT_z/2$. Where $T_z$ is the z-axis distance.

The weak-perspective camera parameters $(s, t_x, t_y)$, which represent 2D orthographic transformation, could be used to approximate the projection:

$$\begin{bmatrix} f(x+T_x)/T_z \\ f(y+T_y)/T_z \end{bmatrix} = \begin{bmatrix} s(x+t_x) \\ s(y+t_y) \end{bmatrix}, s \times T_z = f, T_x = t_x, T_y = t_y. \quad (1)$$

In previous methods, they either use a constant or estimated $f$, and calculate distance by $T_z = f/s$. On contrary, we estimate $T_z$ based on human body distortion clues and calculate $f$ by $f = s \times T_z$. (NDC space)

## Proposed Pipeline



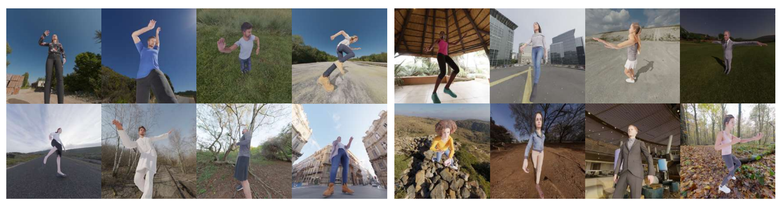

- **Translation Estimation Module.** We use a Transformer to regress the z-axis distance from the warped $I_{IUV}$ image and use sigmoid then $\times 10$ to restrict $T_z$ less than 10m.
- **Mesh Estimation Module.** We adopt an MLP structure to predict the coordinates of a coarse mesh of the body, then up-sample the mesh using two fully connected layers.
- **Loss Functions.** The total loss function is the summation of mesh loss, translation loss, and re-projection loss.

$$\mathcal{L}_{total} = \mathcal{L}_{Mesh} + \mathcal{L}_{Transl} + \mathcal{L}^W_{2D} + \mathcal{L}^P_{2D} \quad (2)$$

where the $\mathcal{L}_{2D^W}$ is the weak-perspective and $\mathcal{L}_{2D^P}$ is the perspective projection.

## New Virtual Dataset: PDHuman

- **Amount**: 126,198 images in the training and 27,448 images in the testing
- **Annotations**: Camera intrinsic matrix, 2D/3D keypoints, SMPL parameters $\boldsymbol{\theta}$, $\boldsymbol{\beta}$, and translation.
- **Camera**: Use the dolly-zoom effect to generate random camera intrinsic matrices.
- **Rendering**: Use human models from RenderPeople and body pose sequences from Mixamo, with HDRi images as backgrounds.



## Experiments

- Results on ordinary datasets and distorted datasets.

| Method | Backbone | 3DPW | | | Human3.6M | |
|---|---|---|---|---|---|---|
| | | PA-JPE | MPJPE | PVE | PA-JPE | MPJPE |
| HMR | Res50 | 72.6 | 116.5 | - | 56.8 | 88.0 |
| SPEC | Res50 | 52.7 | 96.4 | - | | |
| CLIFF | HR48 | 43.0 | 69.0 | 81.2 | 32.7 | 47.1 |
| Zolly | HR48 | **39.8** | **65.0** | **76.3** | **32.3** | **49.4** |

| Method | Backbone | PDHuman (p5) | | | SPEC-MTP (p3) | | |
|---|---|---|---|---|---|---|---|
| | | PA-JPE | PVE | mIoU | PA-JPE | PVE | mIoU |
| HMR | Res50 | 62.5 | 106.7 | 21.7 | 73.9 | 145.6 | 16.0 |
| SPEC | Res50 | 65.8 | 109.6 | 19.6 | 76.0 | 144.6 | 18.8 |
| CLIFF | HR48 | 66.2 | 115.2 | 24.8 | 74.3 | 132.4 | 23.7 |
| Zolly | HR48 | **49.9** | **82.0** | **26.5** | **67.4** | **126.7** | **30.4** |

## Quality Results

**Qualitative results of SOTA methods.** Row 1: PDHuman test. Row 2, 3, 4: web images. Row 4: SPEC-MTP. Row 6: 3DPW. The number under each image represents predicted/ground-truth $f$, FoV angle, and $T_z$. The focal lengths here are all transformed to pixels in full image.