DH-AUG: DH Forward Kinematics Model Driven Augmentation for 3D Human Pose Estimation

Linzhi Huang, Jiahao Liang, and Weihong Deng*
Beijing University of Posts and Telecommunications

Motivation

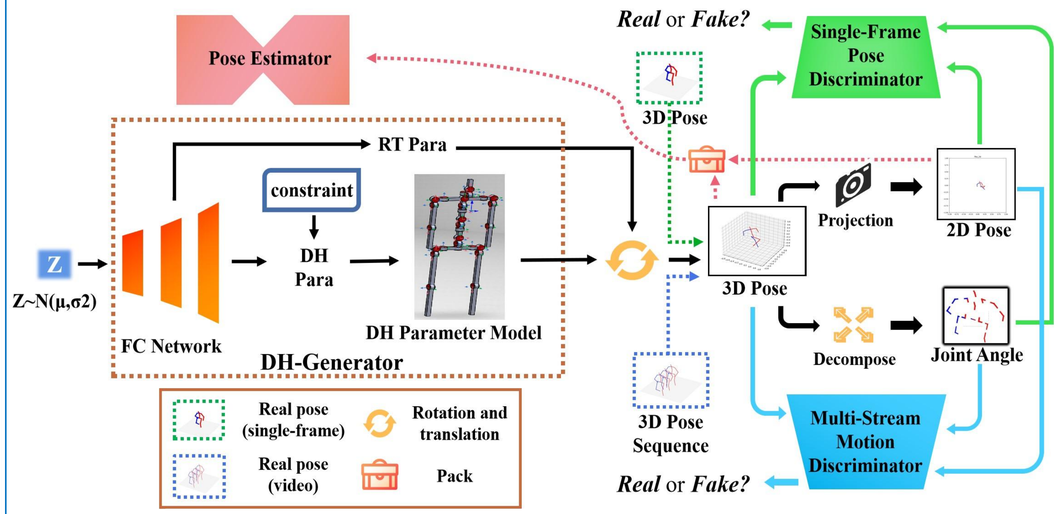
Due to the lack of diversity of datasets, the generalization ability of the pose estimator is poor. To solve this problem, we propose a pose augmentation solution via DH forward kinematics model, which we call DH-AUG. We observe that the previous work is all based on single-frame human pose augmentation, if it is directly applied to video human pose estimator, there will be several previously ignored problems: (i) angle ambiguity in bone rotation (multiple solutions); (ii) the generated skeleton video lacks movement continuity. To solve these problems, we propose a special generator based on DH forward kinematics model, which is called DH-generator.

Contributions

--- We propose DH-AUG: a pose augmentation framework for 3D human pose estimation. It consists of DH-Generator, DH parameter model, single-frame pose discriminator and multi-stream motion discriminator.
--- We use DH parameters to design a human kinematics model, called DH parameter model. By adding DH parameter model and constraints to the generator, the angle ambiguity is successfully weakened and the possibility of generating unreasonable pose is reduced.
--- Extensive experiments demonstrate that DH-AUG can greatly increase the generalization ability of the video pose estimator. In addition, when applied to a single-frame 3D pose estimator, our method outperforms the previous best pose augmentation method.
--- We release a new dataset (DH-3DP) synthesized with DH-AUG, which can be used in the 2D-to-3D network.

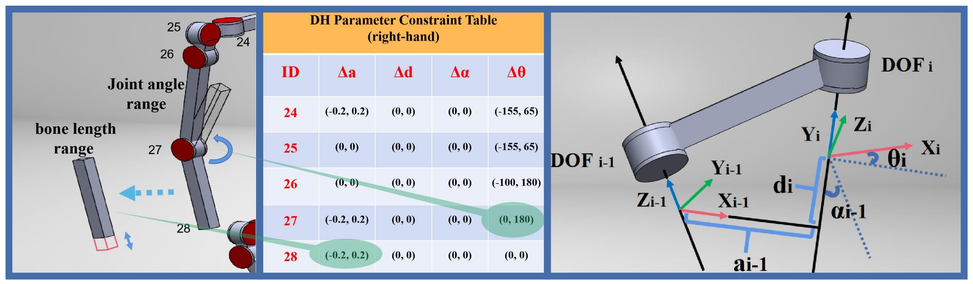
The Proposed Methods

- Overall framework of DH-AUG



$$M_{DH} = \begin{bmatrix} cos(\theta) & -sin(\theta) & 0 & a \\ sin(\theta)cos(\alpha) & cos(\theta)cos(\alpha) & -sin(\alpha) & -dsin(\alpha) \\ sin(\theta)sin(\alpha) & cos(\theta)sin(\alpha) & cos(\alpha) & dcos(\alpha) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- **Left:** The constraint diagram of the elbow. **Middle:** DH parameter constraint table. **Right:** The schematic diagram of DH parameter



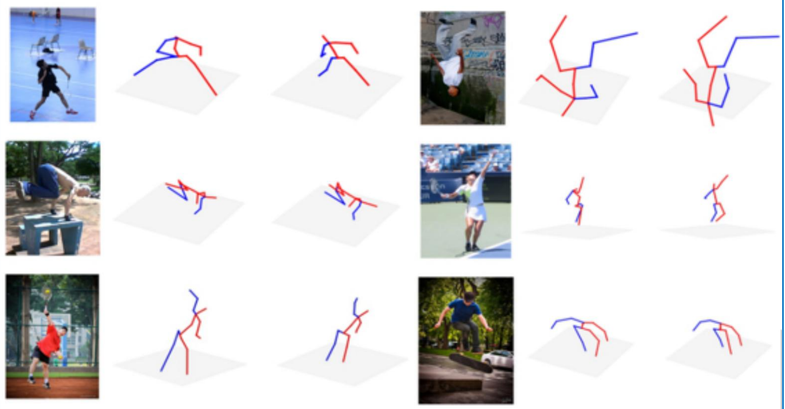
$$P_{DH} = (1 + \tanh(O_{FC})) \frac{T_{DH(max)} - T_{DH(min)}}{2}$$

Results on H36M, MPI and 3DPW

Method	MPI-3DHP (↓) DET	CPN	HR	GT	H36M (↓) DET	CPN	HR	GT
VPose [34] (f=9)	97.56	94.26	90.83	90.7	61.47	55.74	53.79	42.14
Vpose+DH-AUG (f=9)	**84.23**	**84.76**	**82.57**	**80.39**	**60.81**	**55.66**	**53.04**	**41.21**
VPose [34] (f=27)	101.99	97.33	94.62	91.76	61.84	56.57	52.89	42.18
Vpose + DH-AUG (f=27)	**86.34**	**88.38**	**84.37**	**80.85**	**61.19**	**56.07**	**52.57**	**41.52**
PoseFormer [52] (f=9)	95.09	88.01	82.38	85.28	63.28	56.47	54.24	42.02
PoseFormer + DH-AUG (f=9)	**81.99**	**81.13**	**76.07**	**76.25**	**63.13**	**55.73**	**53.32**	**39.29**
PoseFormer [52] (f=27)	92.71	86.38	83.16	84.67	62.26	55.00	53.34	39.63
PoseFormer + DH-AUG (f=27)	**81.04**	**77.13**	**72.18**	**75.36**	**62.26**	**54.95**	**52.46**	**37.92**

Method	MPI-3DHP (↓) DET	CPN	HR	GT	H36M (↓) DET	CPN	HR	GT	3DPW (↓) GT
SemGCN [51]	101.90	98.70	95.60	97.40	67.50	64.70	57.50	44.40	102.00
SemGCN + PoseAug [11]	89.90	89.30	89.10	86.10	65.20	60.00	55.00	41.50	82.20
SemGCN + DH-AUG	**79.68**	**76.67**	**72.99**	**71.31**	**63.16**	**56.93**	**54.04**	**40.00**	**79.07**
SimpleBaseline [28]	91.10	88.80	86.40	85.30	60.50	55.60	53.00	43.30	89.40
SimpleBaseline + PoseAug [11]	78.70	78.70	76.40	76.20	58.00	53.40	51.30	39.40	**78.10**
SimpleBaseline + DH-AUG	**77.99**	**75.87**	**72.97**	**72.28**	**57.86**	**53.13**	**50.06**	**38.89**	80.52
VPose [34] (1-frame)	92.60	89.80	85.60	86.60	60.00	55.20	52.70	41.80	94.60
VPose + PoseAug [11]	78.30	78.40	73.20	73.00	57.80	52.90	50.20	38.20	81.60
VPose + DH-AUG (1-frame)	**76.70**	**74.82**	**71.07**	**71.17**	**57.66**	**52.52**	**49.81**	**37.01**	**79.28**

Qualitative Results



Data Distribution

(L): Data distribution of H36M datasets (before pose augmentation). (M): Pose augmentation (no constraints). (R): Pose augmentation (add constraints).