Prior-Aware Synthetic Data to the Rescue: Animal Pose Estimation with Very Limited Real Data

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BMVC 2022

Problem

Human share the world with and learn the behavior from with billions of animals. **However, low cooperativity and high species diversity prevent us from building comprehensive large-scale datasets to know our neighbors.** Further, the small data training is like cultivating on a tundra.

- Small data training makes the model lack of robustness and thus difficult to cope with more free-ranging movements, occlusions and environments.
- The synthetic animal data used as a supplement lacks realism of poses and it is difficult to be blended into the real background.

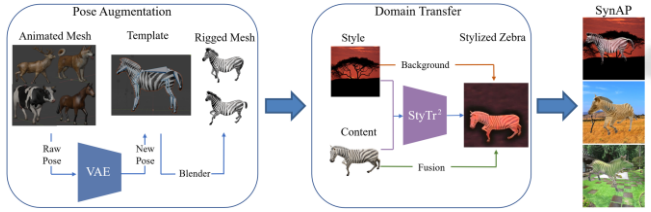
Approach

We present a cost-effective and generic prior-aware synthetic data generation pipeline, called **PASyn**, for animals pose estimate tasks that suffer from severe data scarcity.

- A novel variational autoencoder (VAE)-based synthetic animal data generation pipeline PASyn to generate probabilistically-valid pose data
- A style transfer strategy to militate the inconsistency between synthetic animal and real background
- A synthetic animal pose (SynAP) dataset, containing 3,000 zebra images and 3,600 images of six common quadrupeds

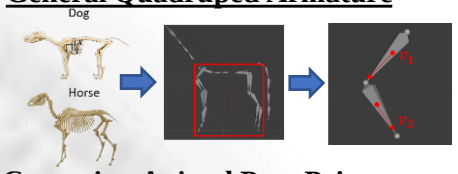
Prior-Aware Synthetic Data Generation

Our Prior-Aware Synthetic Data Generation (PASyn) Pipeline includes three main steps:



Pose Augmentation

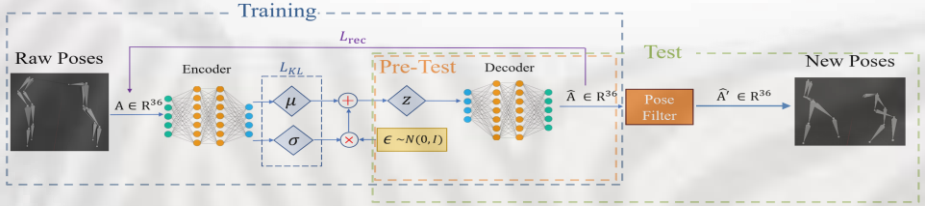
General Quadruped Armature



Training

$$\mathcal{L}_{\text{total}} = w_1\mathcal{L}_{KL} + w_2\mathcal{L}_{\text{rec}},$$
$$\mathcal{L}_{KL} = KL(q(z|A)||\mathcal{N}(0,I)),$$
$$\mathcal{L}_{\text{rec}} = \|A - \hat{A}\|_2^2$$

Capturing Animal Pose Prior

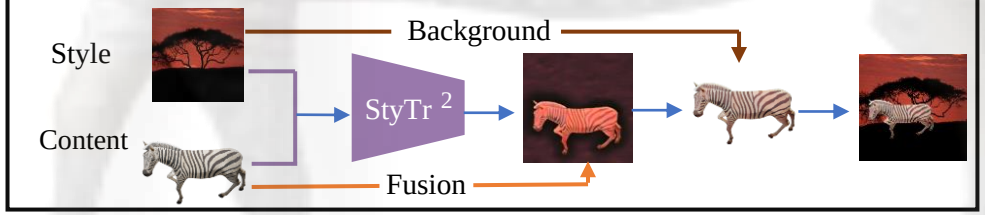


Stylization

Why style transfer

- Enrich the texture diversity in a reasonable way
- Blend the synthetic animal image into the real backgrounds

Architecture



Synthetic Animal Pose (SynAP) Dataset

Size

SynAP contains **3,000** synthetic zebra images and SynAP+ extends the SynAP with **3,600** images of horses, cows, sheep, dogs, giraffes and deer.

Background

300 grass, savanna, and forest real scenes are collected from Internet to stylize the synthetic animal.

Results

- Evaluation Over SynAP

Method	Backbone	Training Set	PCK@0.05 Pose Estimation Accuracy on Zebra-300 Set										
			Eye	Nose	Neck	Shoulders	Elbows	F-Paws	Hips	Knees	B-Paws	RoT	Average
MMPose [0]	HRNet-w32	R(99)	97.3	95.8	**83.2**	78.8	77.1	62.6	86.0	74.9	59.8	82.4	78.7
		R(99)+ S(3K)	**97.8**	**98.3**	81.1	**94.0**	**93.5**	**92.0**	93.7	93.5	89.0	**87.6**	**92.4**
		R(99)+ S(5K)	97.5	96.9	81.8	89.6	91.3	90.7	**94.1**	**94.1**	**90.4**	86.0	91.6
DeepLabCut [■]	EfficientNet-B6	R(99)	93.7	96.2	**82.5**	**91.4**	80.8	67.4	88.1	84.5	71.8	83.2	83.6
		R(99)+ S(3K)	**95.1**	**97.9**	81.5	90.1	83.3	75.5	**93.2**	89.3	83.9	86.8	87.6
		R(99)+ S(5K)	94.1	92.6	80.8	90.8	**87.0**	**85.7**	90.5	**93.3**	**88.3**	**86.8**	**89.2**
MMPose [0]	ResNet-50	R(99)	96.2	96.9	**80.8**	59.0	71.3	71.2	88.5	78.2	59.3	85.2	76.9
		R(99)+ S(3K)	95.6	95.8	69.9	**87.3**	**84.6**	84.3	90.8	91.2	84.4	77.2	86.7
		R(99)+ S(5K)	**97.0**	**97.9**	74.5	85.3	84.2	**84.5**	**94.6**	**91.4**	**88.0**	**85.6**	**88.4**

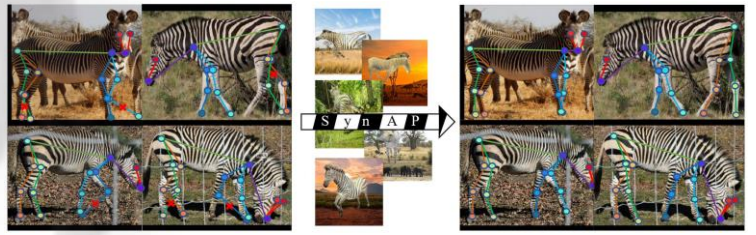
- The effect of SynAP with large real data

Training Set	Real Zebra	PCK@0.05 Pose Estimation Accuracy on Zebra-300 Set										
		Eye	Nose	Neck	Shoulders	Elbows	F-Paws	Hips	Knees	B-Paws	RoT	Average
R(8K) (SOTA)	✓	**97.5**	97.2	79.4	87.8	90.3	93.8	95.3	94.1	89.5	86.4	91.4
R(8K) + S(3K)	✓	97.3	**98.3**	79.0	93.1	94.9	96.0	95.3	**96.7**	93.3	**89.6**	93.8
R(8K) + S(5K)	✓	97.3	97.6	**81.1**	**93.7**	**95.7**	**96.0**	**96.6**	96.0	**94.3**	87.6	**94.2**
R(8K)	✗	79.7	87.7	37.4	77.6	80.0	87.6	82.0	86.4	81.3	67.2	78.3
R(8K) + S(3K)	✗	94.8	96.2	**67.1**	90.8	87.9	90.2	87.6	91.6	89.7	77.6	88.2
R(8K) + S(5K)	✗	**97.5**	**96.2**	66.1	**91.6**	**89.5**	**93.8**	**93.9**	**93.5**	**91.1**	**77.6**	**90.2**

- Ablation Study

Index	Training Set	VAE	Style Transfer	σ^2	Zoo Zebra Set	Zebra-300 Set
a	R(99)	✗	✗	✗	76.0	78.7
b	S(3K)	✗	✗	2I	38.7	30.0
c	S(3K)	✓	✗	2I	44.2	36.7
d	S(3K)	✓	✓	2I	42.9	46.6
e	R(99)+S(3K)	✗	✗	2I	89.8	88.0
f	R(99)+S(3K)	✓	✗	2I	90.4	89.8
g	R(99)+S(3K)	✓	✓	I	90.5	91.1
h	R(99)+S(3K)	✓	✓	2I	**91.5**	**92.4**

- Visualized Results



In conclusion, our synthetic animal pose dataset SynAP and its extended version SynAP+, and th of real data is verified on different backbones and achieves state-of-the positive effect of them on pose estimation task of animals with a small amounte-art performance.