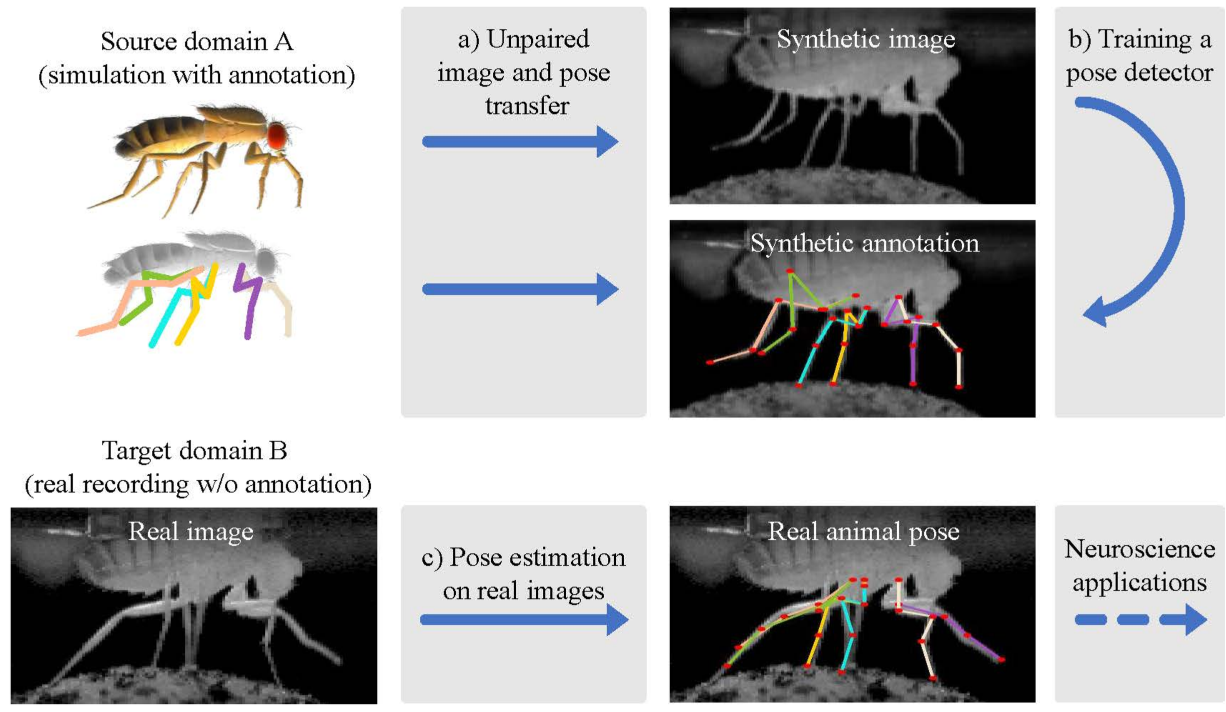
Deformation-aware Unpaired Image Translation for Pose Estimation on Laboratory Animals

Siyuan Li[1], Semih Günel[1], Mirela Ostrek[1], Pavan Ramdya[1], Pascal Fua[1], and Helge Rhodin[1,2]

[1]École polytechnique fédérale de Lausanne [2] The University of British Columbia

Problem Definition

Goal: Capture the pose of real animals using synthetic training examples, **without using any manual annotations**. In order to support the study how neural circuits orchestrate behavior.



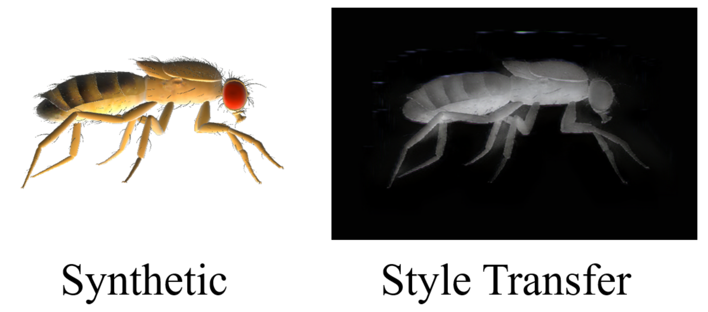
Key Contributions:

- An efficient model that generates both realistic appearances and accurate annotations from simple synthetic animal models.
- Explicit and independent modeling of appearance, shape and pose in an unpaired image translation framework.
- Introducing a pixel-wise deformation module that overcomes large structure difference across domains.

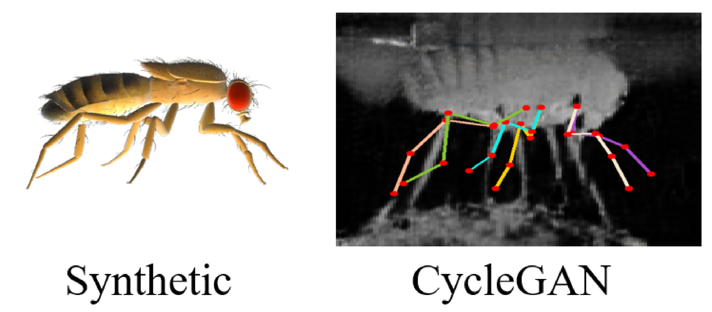
Related Works

Unpaired image translation

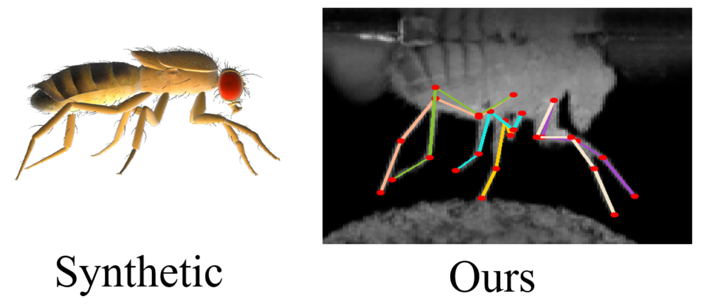
- **Style Transfer based methods** keep the pose unchanged fail to generate realistic appearances.



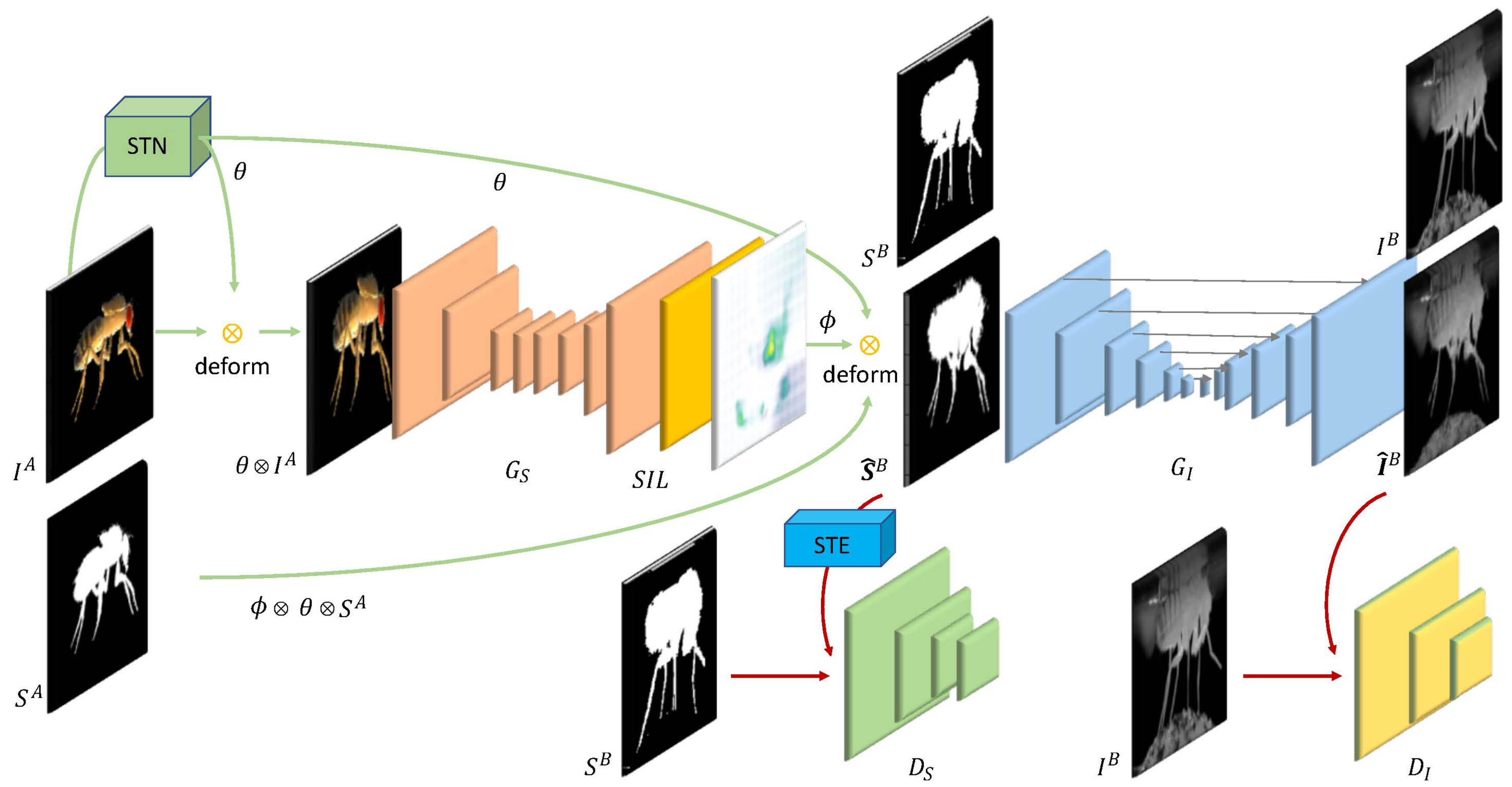
- **cycleGAN based methods** generate realistic appearances fail to keep the pose when source and target domain have large structural differences.



- **Our proposed method** can generate realistic images together with accurate annotations.



Method

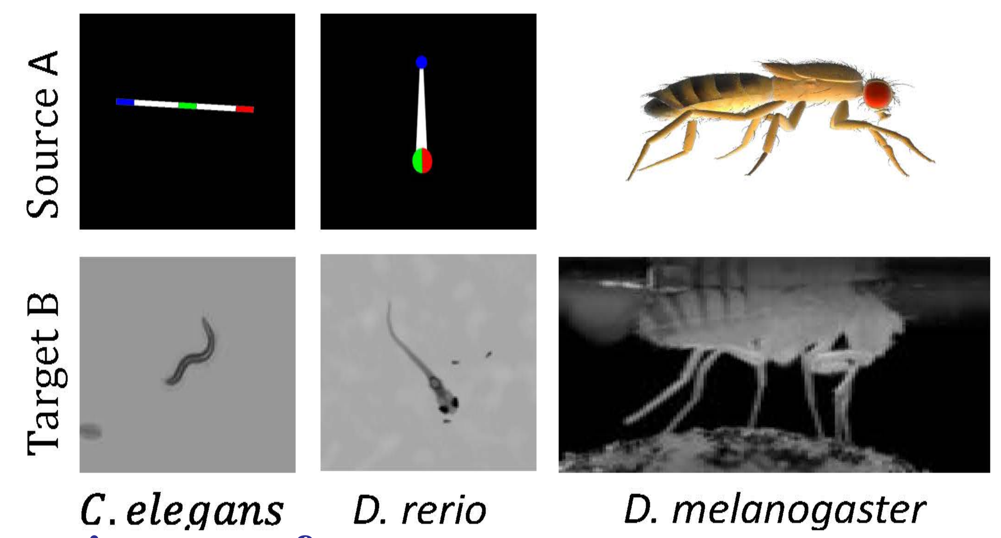


Overview of our deformation-based image translation method. Our model has two steps. In the first step, the deformation from source domain A to target domain B is estimated for input image ^{A} and it's silhouette ^{A} via network G_S and a Spatial Transformer Network (STN). Their output is an explicit deformation field parameterized by the global, affine transformation θ and a local, non-linear warping ϕ, using a spatial integral layer (SIL).Then, the deformed silhouette is transformed into the full output image $\hat{}^B$ with image generator G_I. Discriminators D_S and D_I enable unpaired training. D_S uses the Straight Through Estimator (STE) for backpropagation.

Experiments: image translation

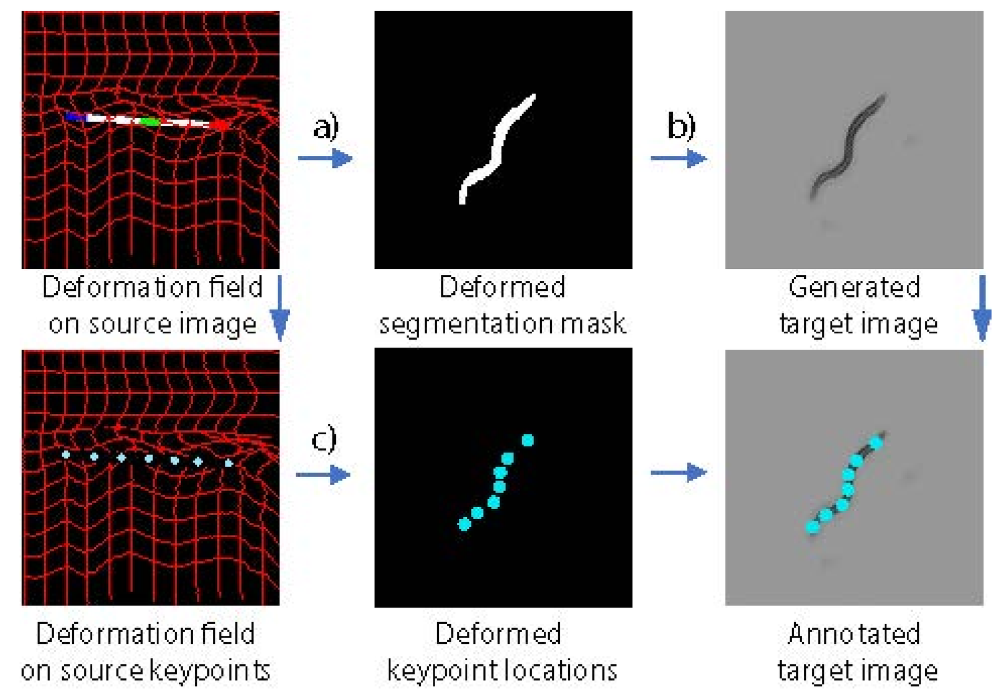
Dataset overview

- **Samples of synthetic and real data.** We focus on three animals with large discrepancy in appearance, shape and pose.



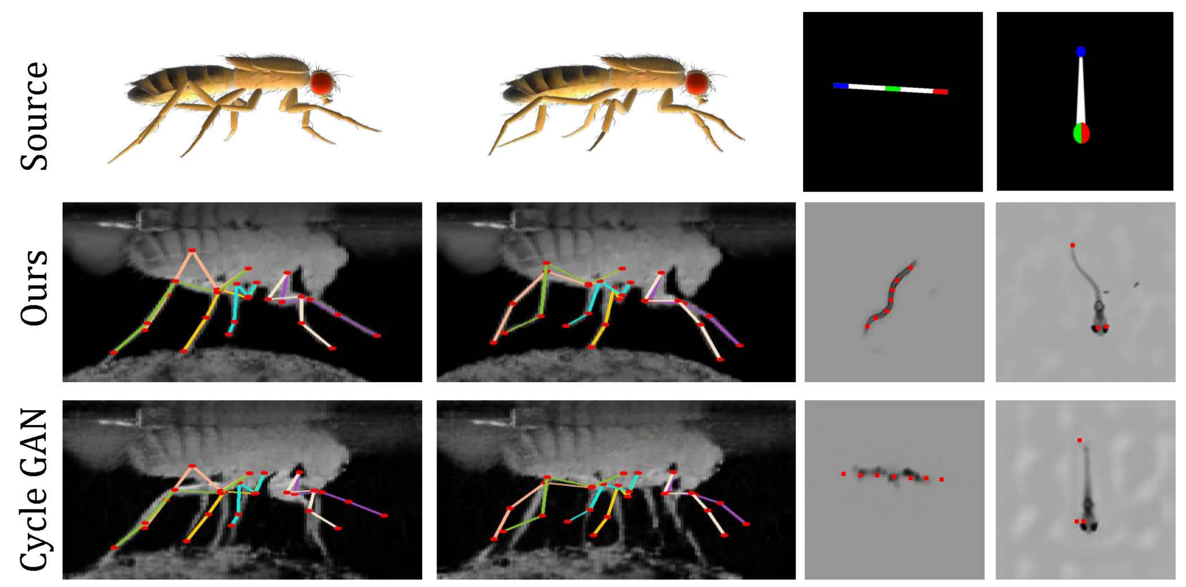
Annotation transfer

- Annotations can be transferred from source to target domain by learned deformation field.



Results

- **Qualitative comparison.** Our methods can generate realistic images with accurate annotations in target domain



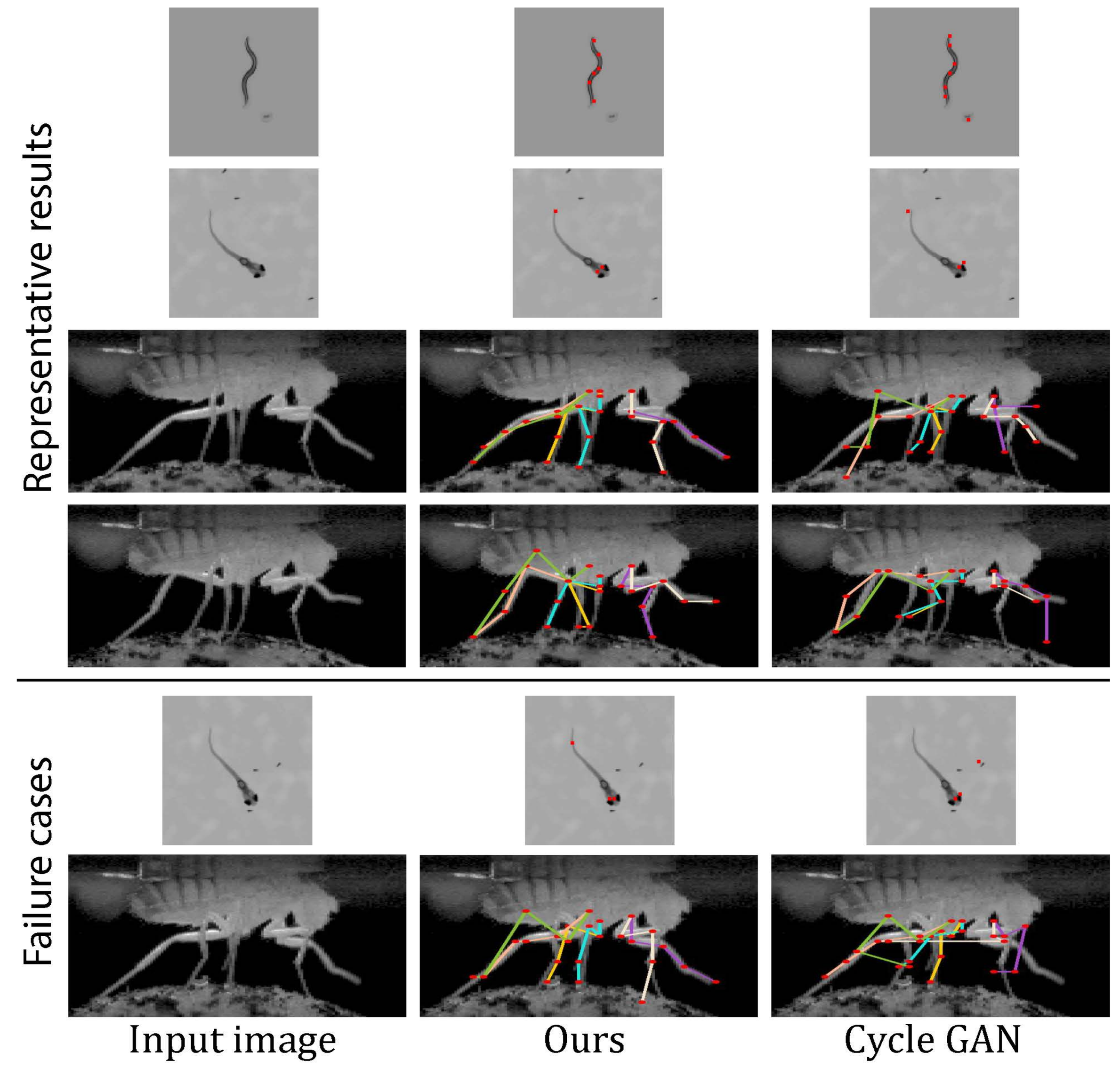
- **Structured similarity (SSIM) comparison.**

Task	*D.M.*	*C.E.*	*D.E.*
Fast-Style-Transfer	0.3932	0.0539	0.6385
Cycle-GAN	0.6543	0.9034	0.8504
Gc-GAN	0.6392	0.8915	0.8586
Ours	**0.6746**	**0.9076**	**0.8771**

Experiments: pose estimation

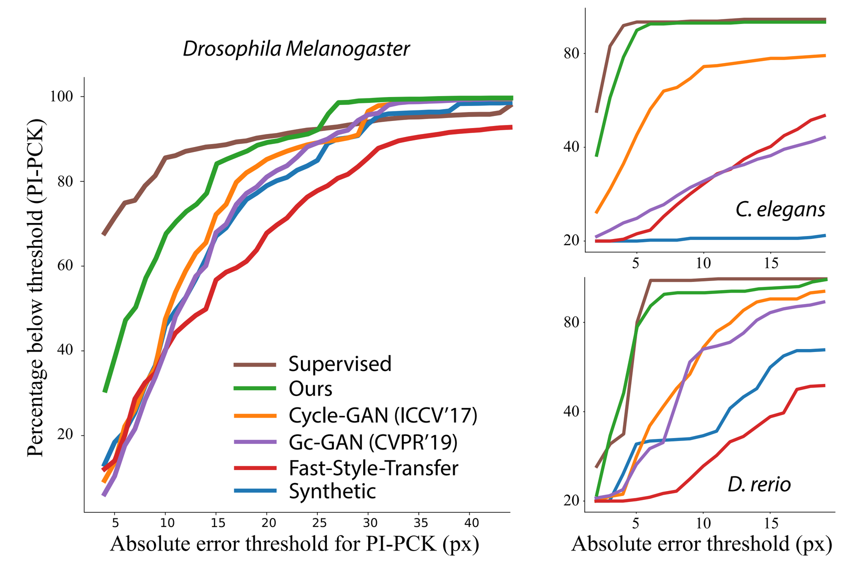
Qualitative results

- The estimator provides close to fully-supervised results across all three animals.



Quantitative results

- **Pose estimation accuracy**



- Pose estimation results for Drosophila:

Metric	*Drosophila Melanogaster* PI-PCK ↑ (5 pix)	PI-PCK ↑ (15 pix)	PI-AUC ↑ (4-45 pix)	PI-RMSE ↓ (pix)
Synthetic	19.8	67.9	75.75	13.456
Fast-Style-Transfer	15.4	57.6	68.9	17.309
Gc-GAN	11.9	68.7	76.3	13.175
Cycle-GAN	15.0	72.9	78.4	12.302
Ours	**40.0**	**84.7**	**86.0**	**8.823**
Supervised	72.2	88.8	90.35	6.507

- Pose estimation results for C.elegans and D. rerio:

	Caenorhabditis elegans			*Danio rerio*		
Metric	PI-PCK ↑ (5 pix)	PI-AUC ↑ (2-20 pix)	PI-RMSE ↓ (pix)	PCK ↑ (10 pix)	AUC ↑ (2-20 pix)	RMSE ↓ (pix)
Synthetic	0.0	0.9	67.29	29.3	37.4	20.15
Fast-Style-Transfer	3.1	25.0	20.50	15.6	20.8	19.25
Gc-GAN	9.7	25.0	27.38	68.2	54.5	27.38
Cycle-GAN	45.3	63.2	14.71	68.7	59.1	9.70
Ours	**90.3**	**87.6**	**5.36**	**93.9**	**83.1**	**4.50**
Supervised	94.6	92.3	3.77	99.6	86.5	3.91