JUNE 18-22, 2023
CVPR
VANCOUVER, CANADA

SOUTHEAST UNIVERSITY
東南大學

Semi-supervised Hand Appearance Recovery via Structure Disentanglement and Dual Adversarial Discrimination

Zimeng Zhao, Binghui Zuo, Zhiyu Long and Yangang Wang

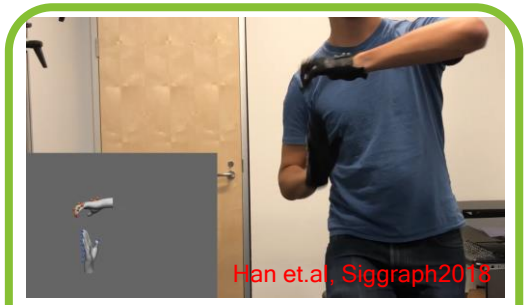
Southeast University

Project Page

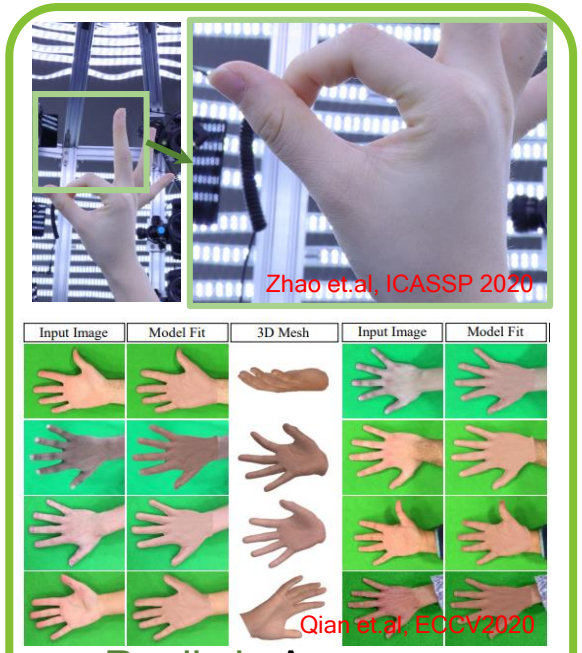
WED-AM-372

Human Hand Data Capture

Separate Acquisition

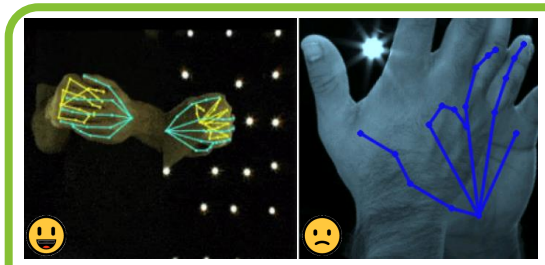


Accurate Pose:
Marker-based Capture

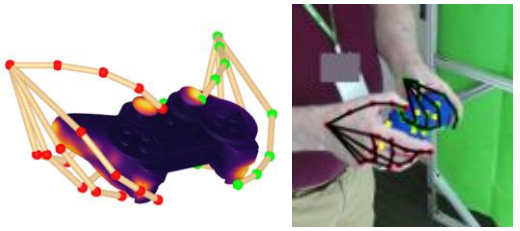


Realistic Appearance:
Bare Skin Capture

Synchronous Acquisition

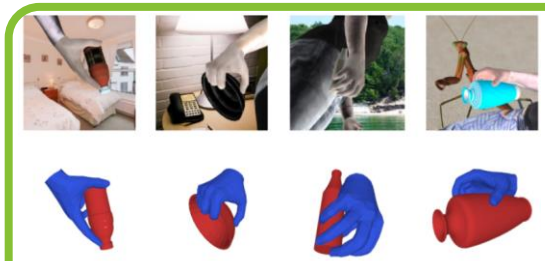


Moon et.al, ECCV 2020



Brahmbhatt et.al, ECCV 2020

Marker-less Procedure with Pose Estimator



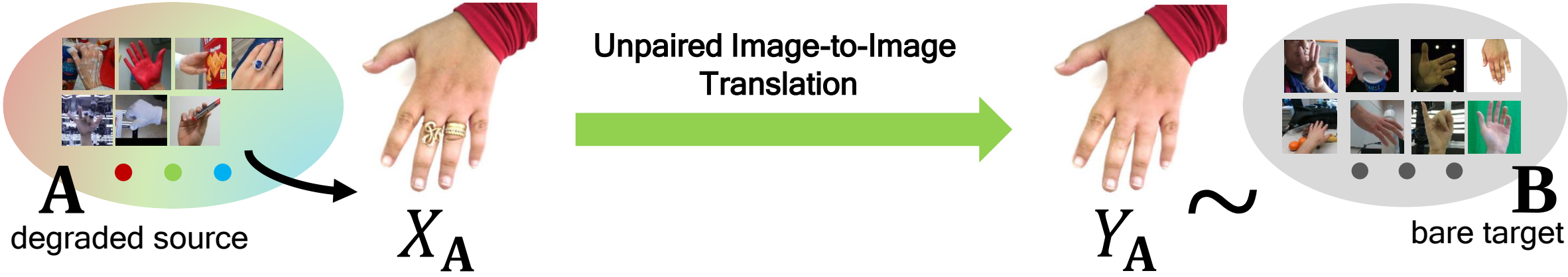
Hasson et.al, CVPR 2022

Gao et.al, NeurIPS 2022

Synthetic Procedure with Differentiable Rendering

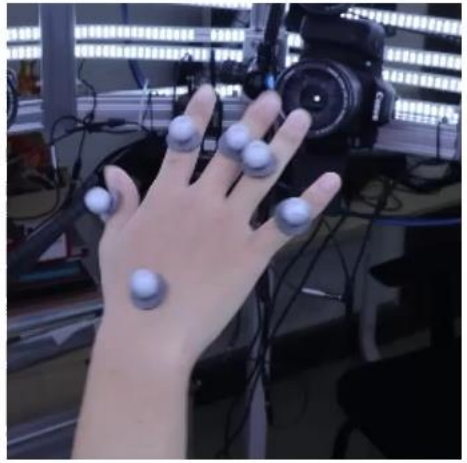
- Pose & Appearance **Synchronous** Acquisition
  - Marker-less Procedure: Depends on the estimator stability
  - Synthetic Procedure: Suffers from the rendering realness

Insight

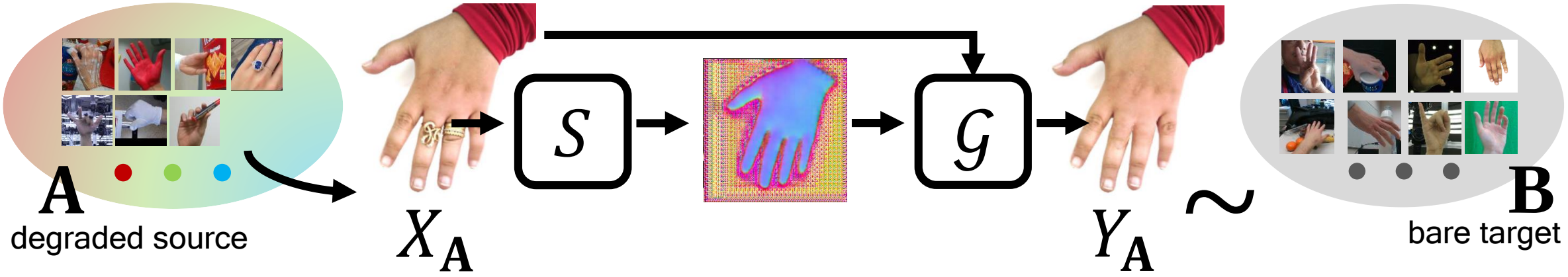

A
degraded source
X_A
Unpaired Image-to-Image Translation
Y_A
~
B
bare target



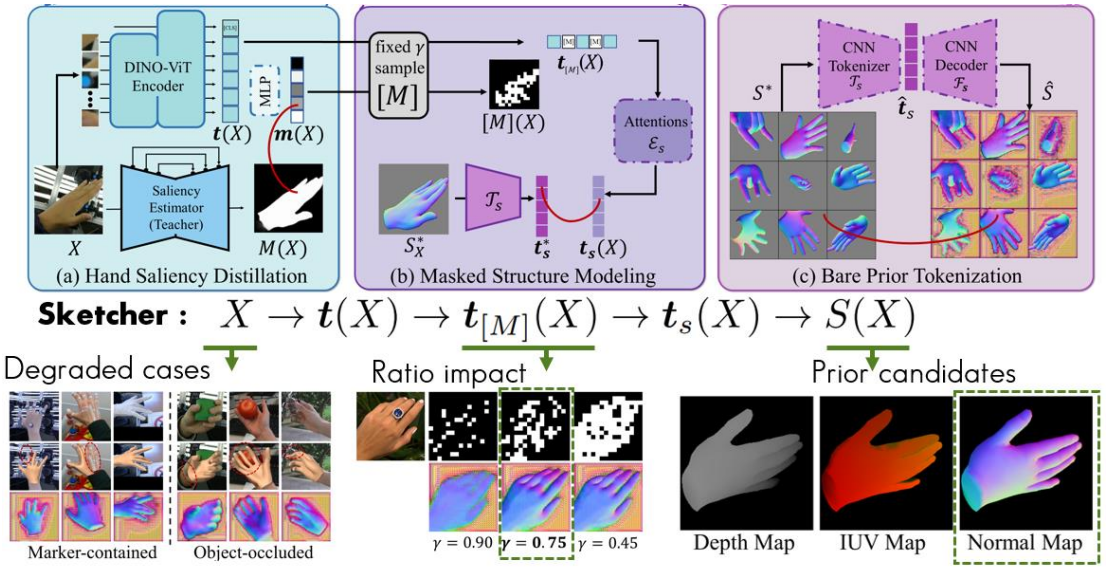




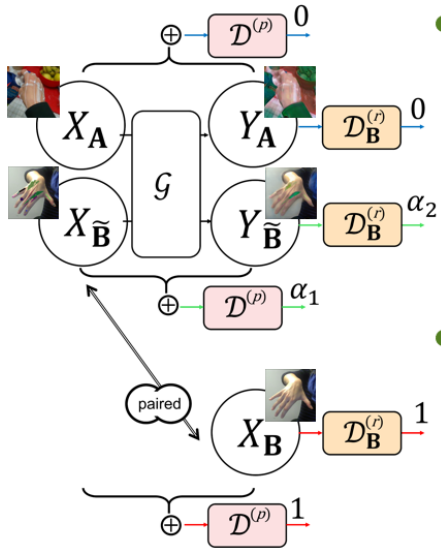
Overview



Structure Disentanglement



Dual Adversarial Discrimination



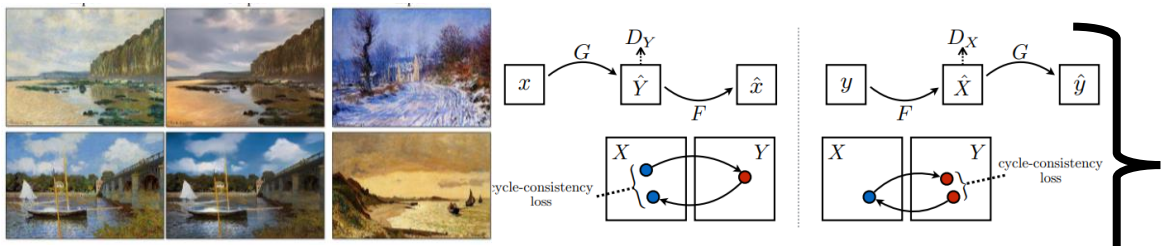
- **Translation loss**

$$
\begin{aligned}
L_{\mathcal{G}} = & \|(Y_{\mathbf{A}}\text{-}X_A) \odot (1\text{-}M[S(X_{\mathbf{A}})])\|_F \\
& + \|(Y_{\tilde{\mathbf{B}}}\text{-}X_{\tilde{\mathbf{B}}}) \odot (1\text{-}M[S(X_{\tilde{\mathbf{B}}})])\|_F \\
& + |\mathcal{D}_{\mathbf{B}}^{(r)}(Y_{\mathbf{A}})\text{-}1| + |\mathcal{D}_{\mathbf{B}}^{(r)}(Y_{\tilde{\mathbf{B}}})\text{-}1| \\
& + |\mathcal{D}^{(p)}(X_{\mathbf{A}} \oplus Y_{\mathbf{A}})\text{-}1| + |\mathcal{D}^{(p)}(X_{\tilde{\mathbf{B}}} \oplus Y_{\tilde{\mathbf{B}}})\text{-}1|
\end{aligned}
$$

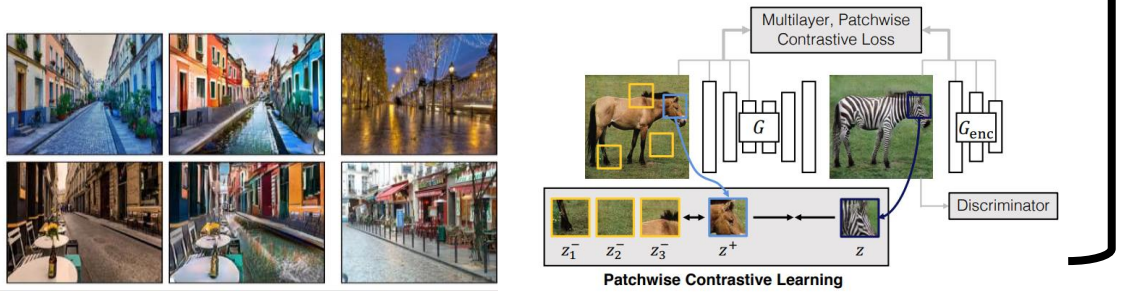
- **Dual-discrimination loss**

$$
\begin{cases}
L_{\mathcal{D}}^{(r)} = |\mathcal{D}_{\mathbf{B}}^{(r)}(\underline{Y_{\mathbf{A}}})\text{-}0| + |\mathcal{D}_{\mathbf{B}}^{(r)}(\underline{Y_{\tilde{\mathbf{B}}}})\text{-}\alpha_2| + |\mathcal{D}_{\mathbf{B}}^{(r)}(X_{\mathbf{B}})\text{-}1| \\
L_{\mathcal{D}}^{(p)} = |\mathcal{D}^{(p)}(X_{\mathbf{A}} \oplus \underline{Y_{\mathbf{A}}})\text{-}0| + |\mathcal{D}^{(p)}(X_{\tilde{\mathbf{B}}} \oplus \underline{Y_{\tilde{\mathbf{B}}}})\text{-}\alpha_1| \\
\qquad + |\mathcal{D}^{(p)}(X_{\tilde{\mathbf{B}}} \oplus X_{\mathbf{B}})\text{-}1|
\end{cases}
$$

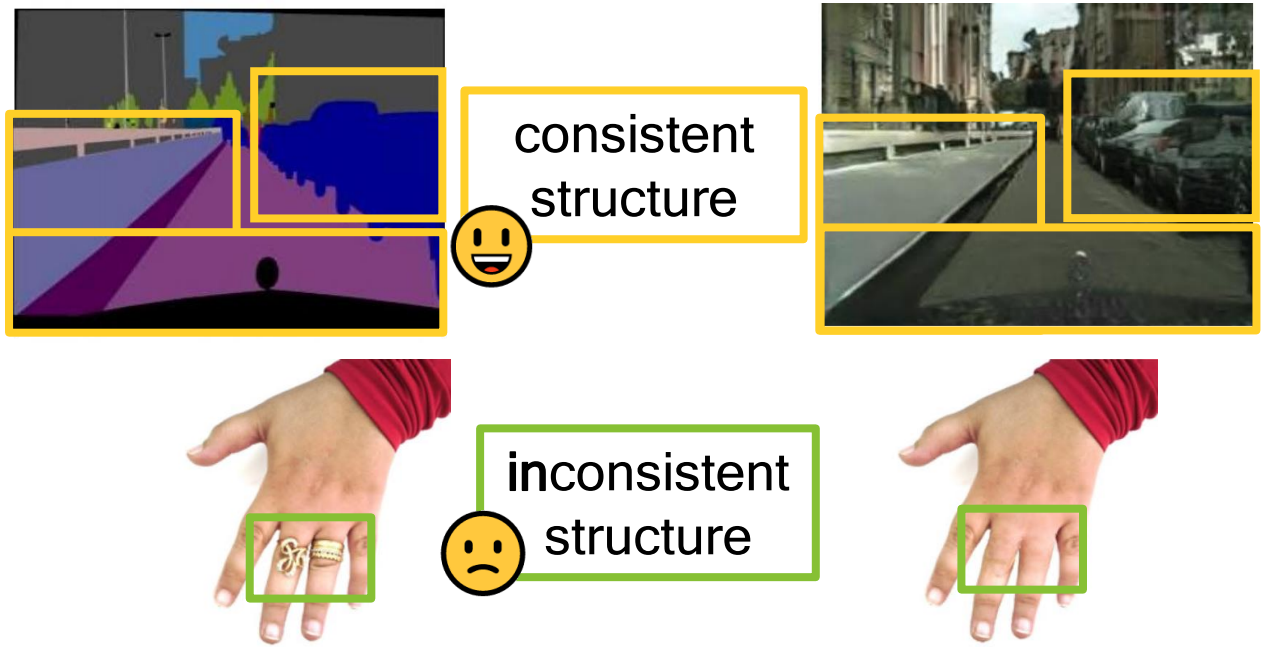
Challenges



CycleGAN, Zhu et.al. ICCV 2017

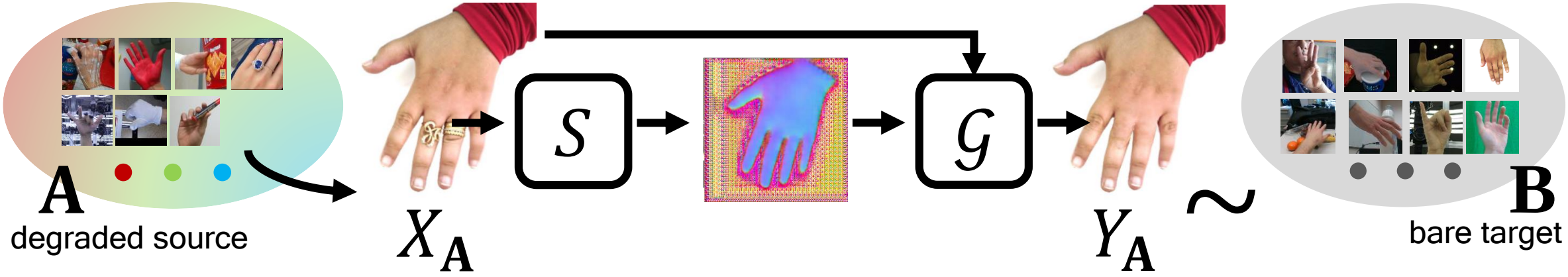


CUT, Park et.al. ECCV 2020



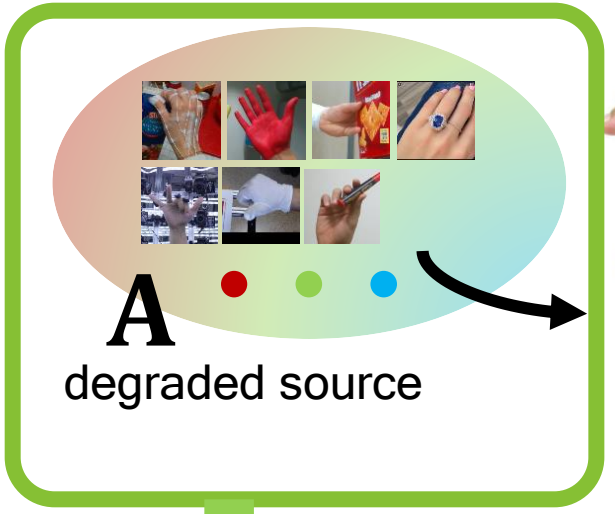
- **Data** : Degraded-bare hand image pairs are almost impossible to obtain.
- **Problem** : Background, foreground hand, and foreground markers require different processing options.
- **Baseline** : Existing unsupervised translators cannot handle the problem with partial structure inconsistency.

Contributions



- A semi-supervised framework that makes degraded images in marker-based MoCap regain bare appearance.
- A powerful ViT sketcher that disentangles bare hand structure without parametric model dependencies.
- An adversarial scheme that promotes the degraded-to-bare appearance wrapping effectively.

Step 1. Structure Disentanglement

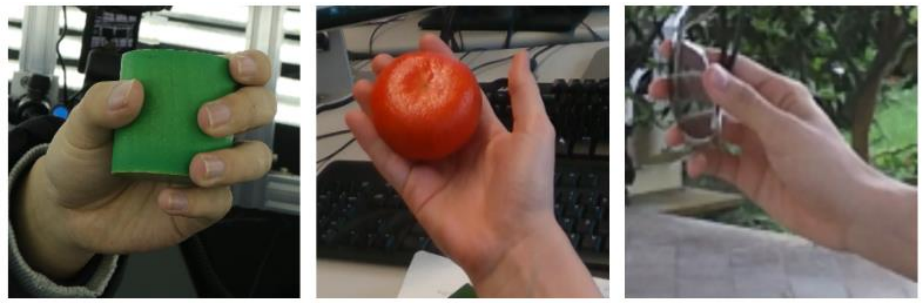


X_A

Y_A ~

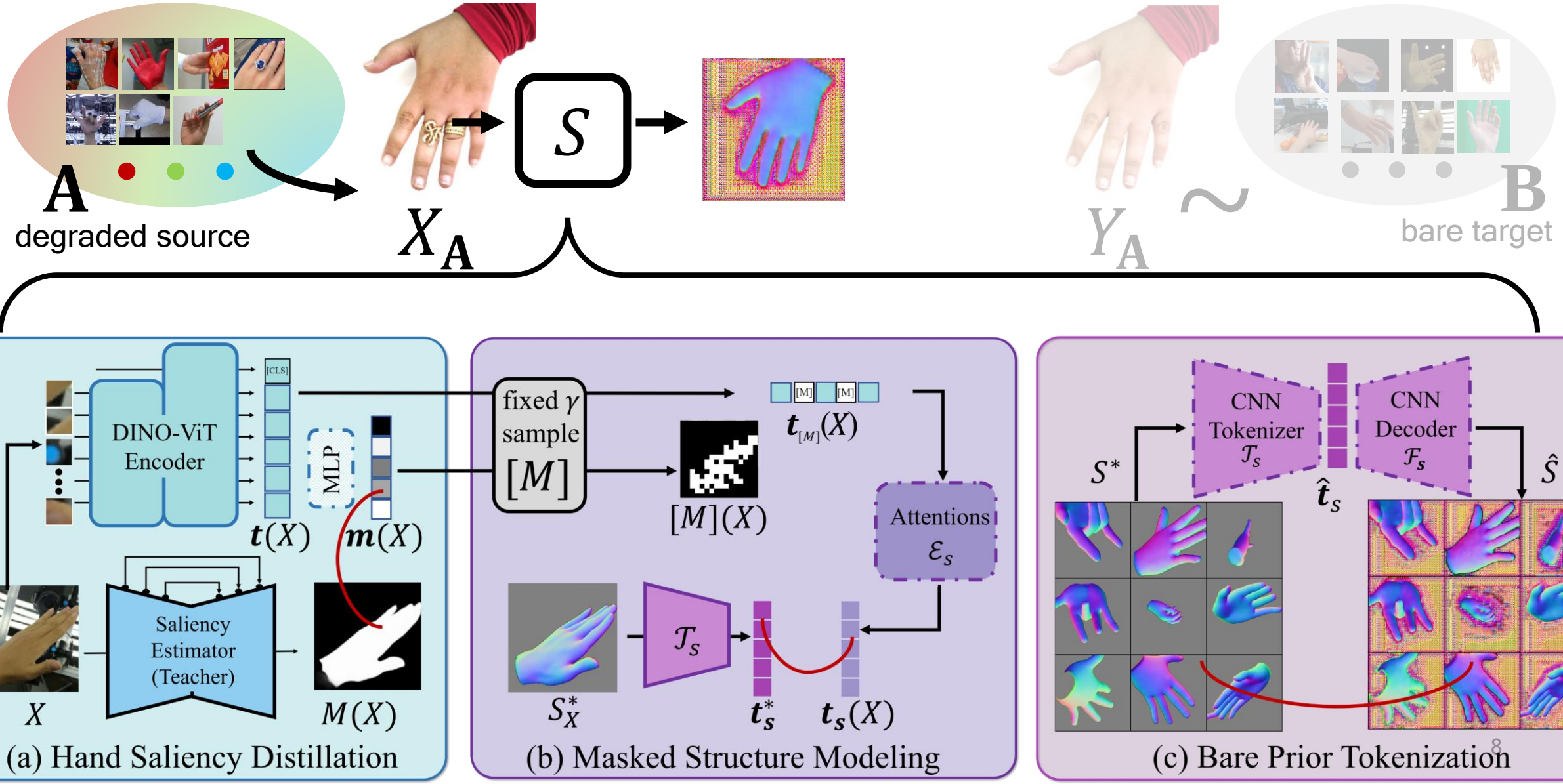
Degraded Cases We Concerned :

Marker-contained

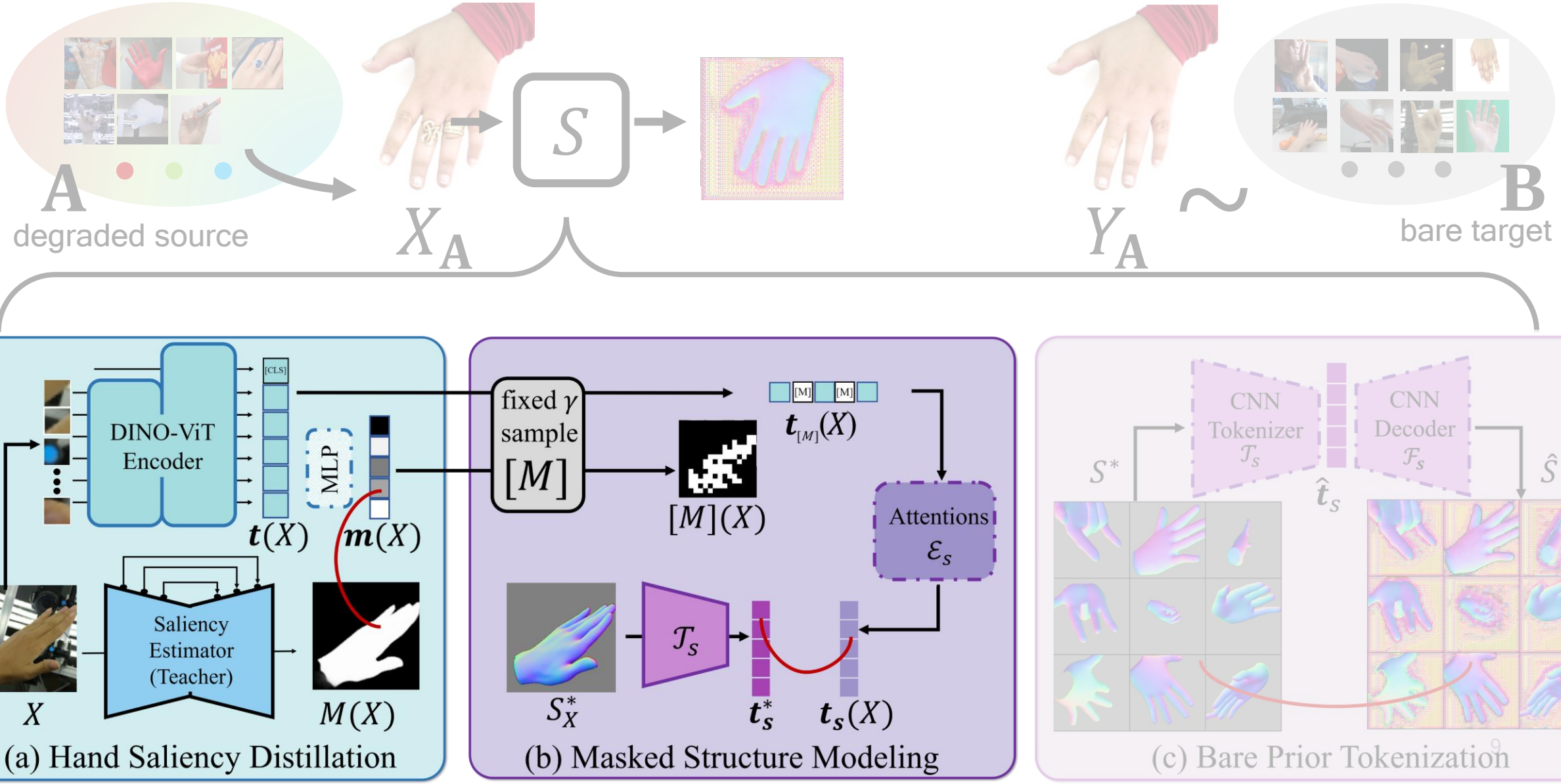


Object-occluded

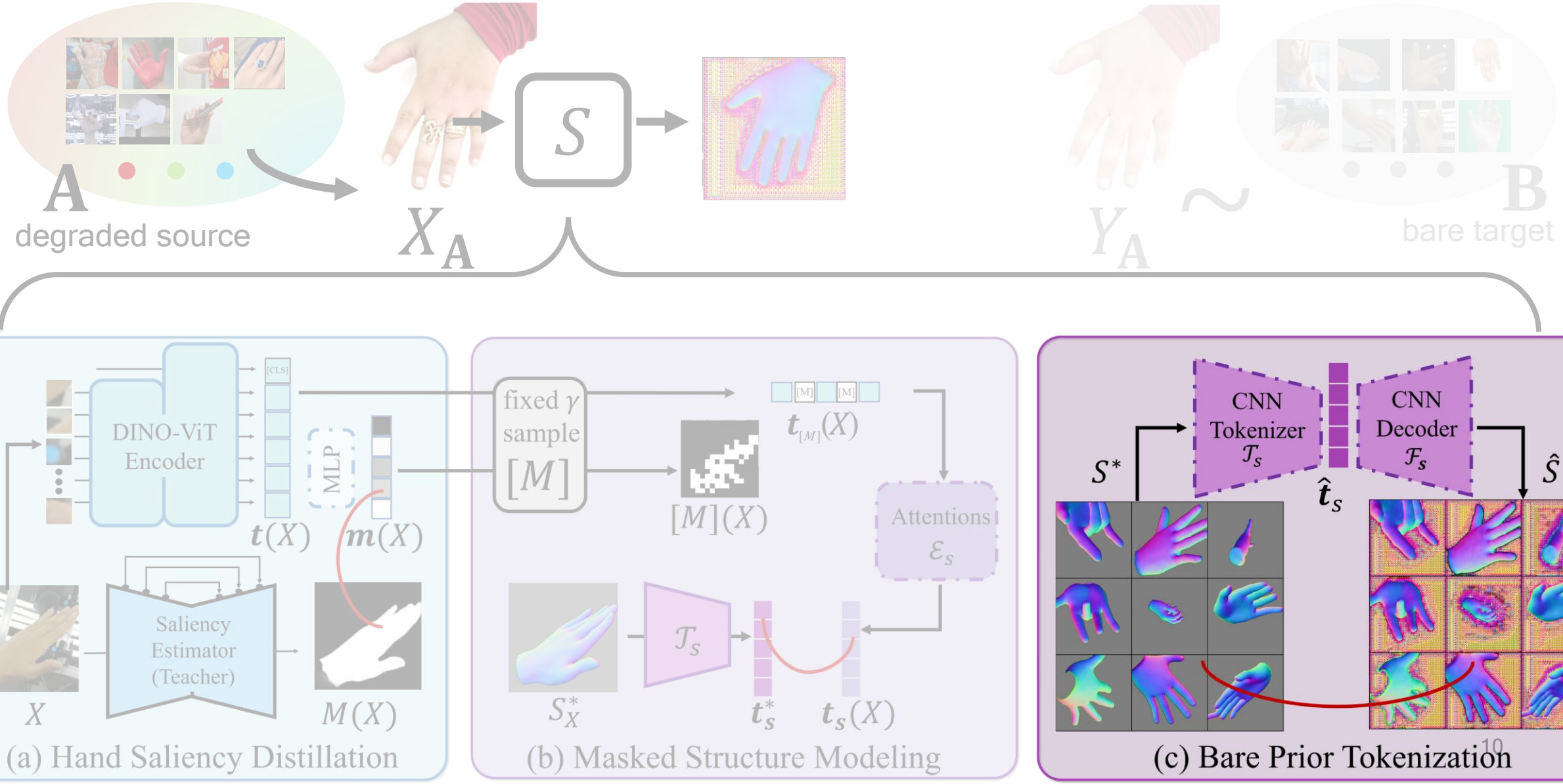
Step 1. Structure Disentanglement



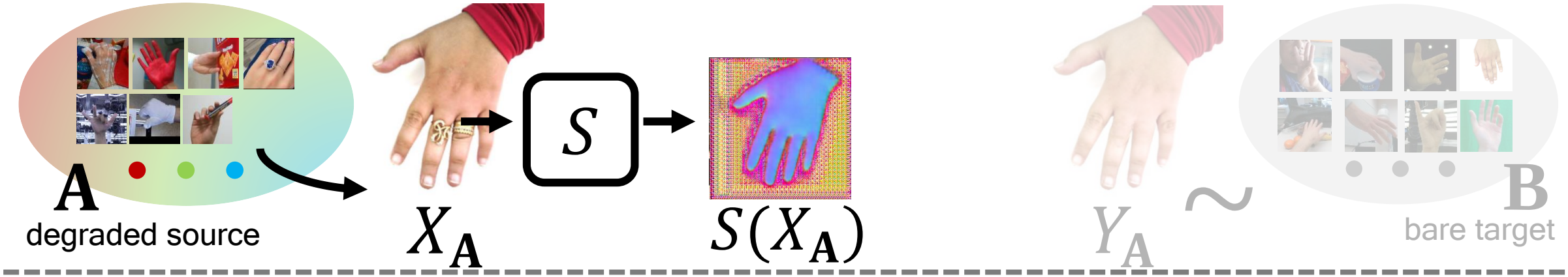
Step 1. Structure Disentanglement



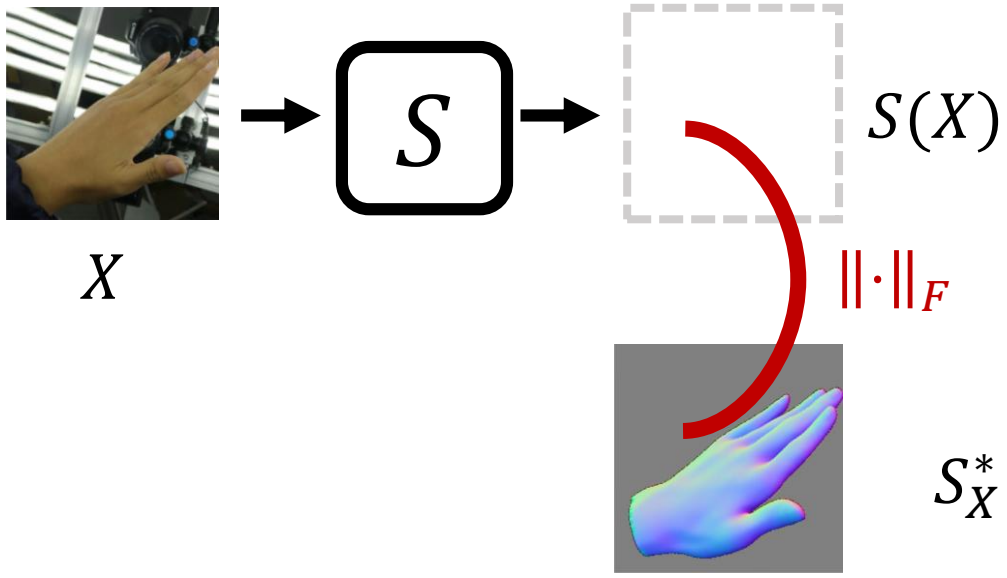
Step 1. Structure Disentanglement



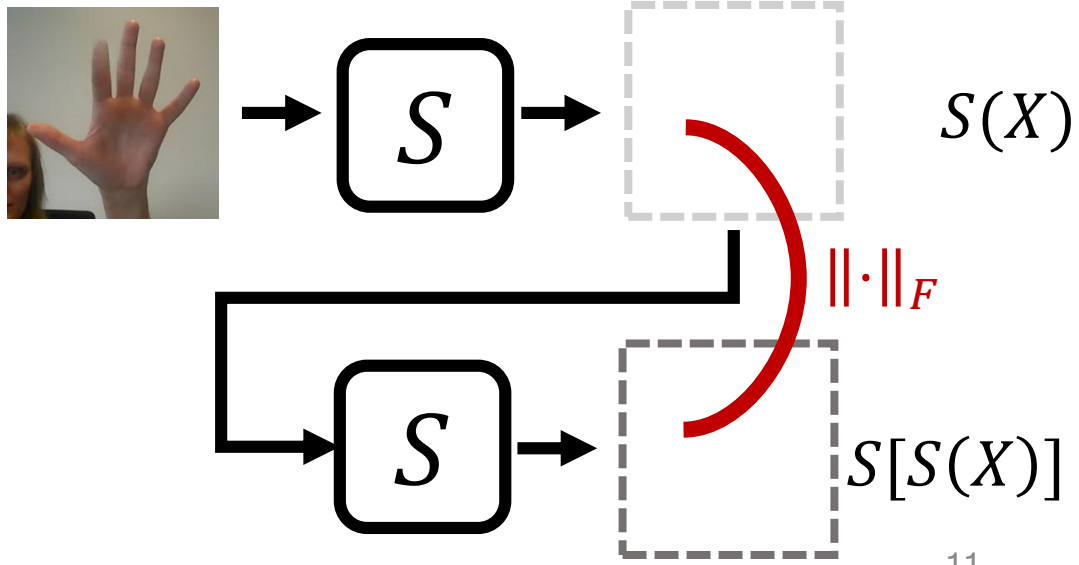
Step 1. Structure Disentanglement



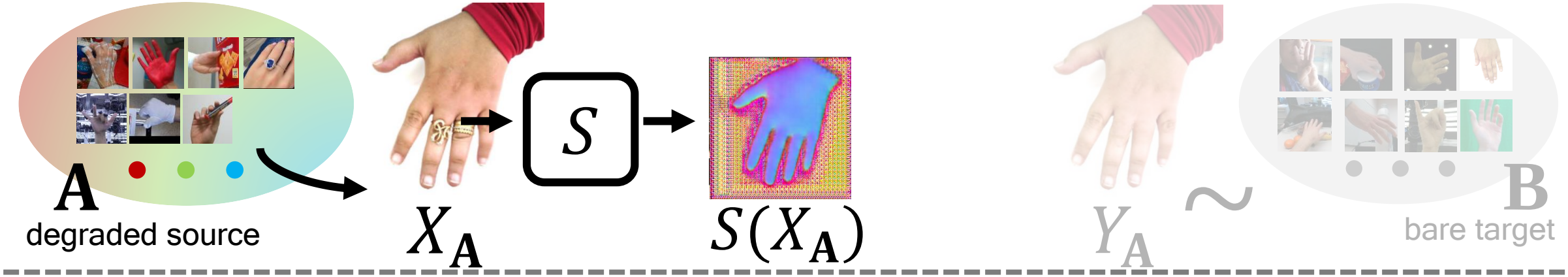
Train with **labeled** data $\{X, S_X^*\}$

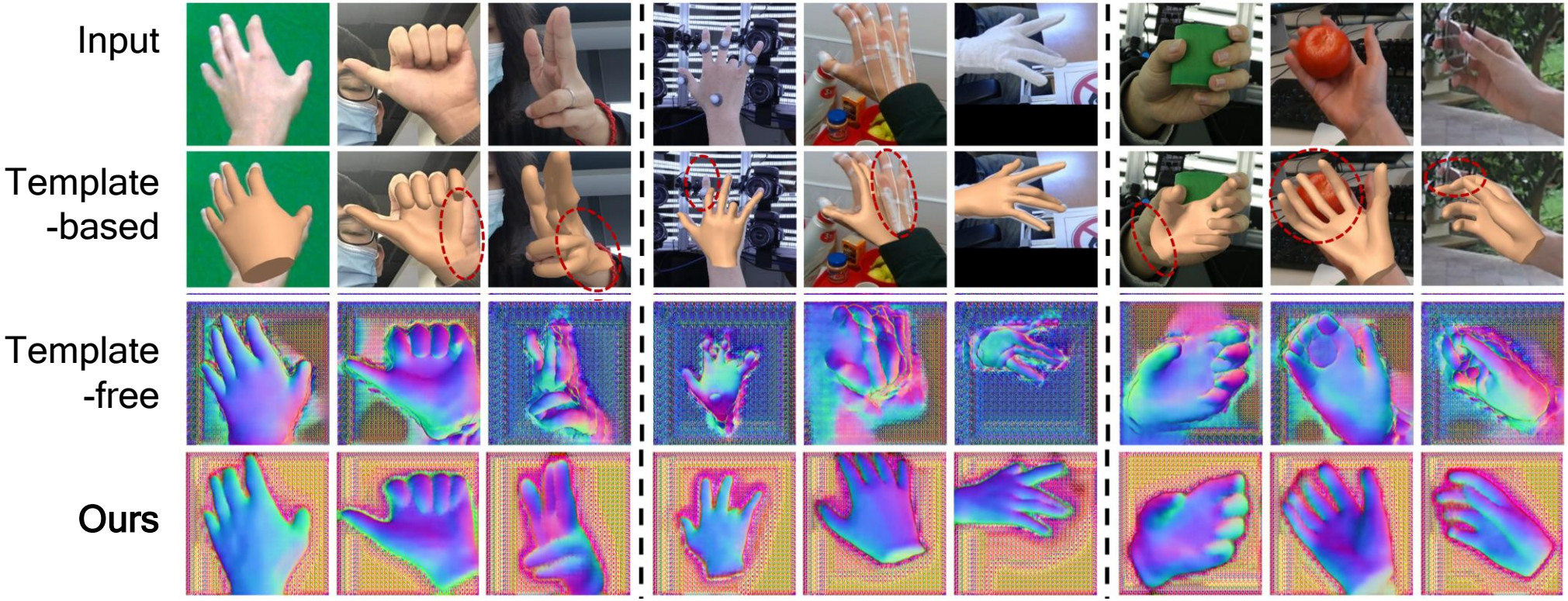


Train with **unlabeled** data $\{X\}$

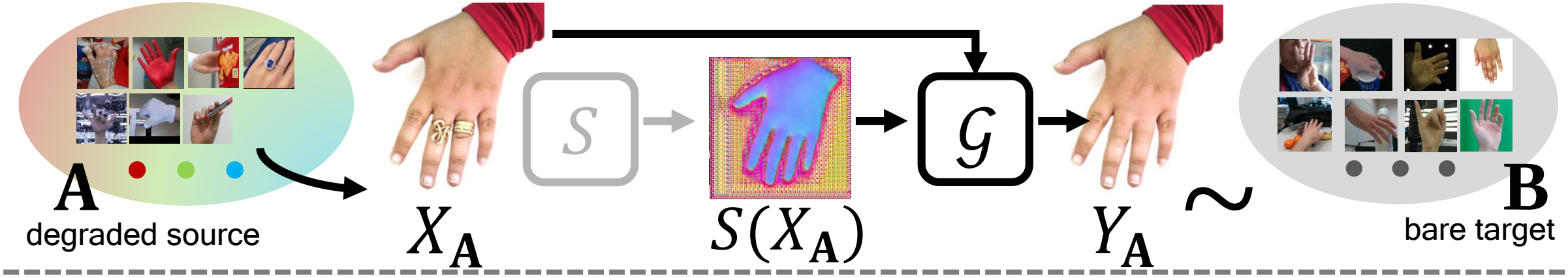


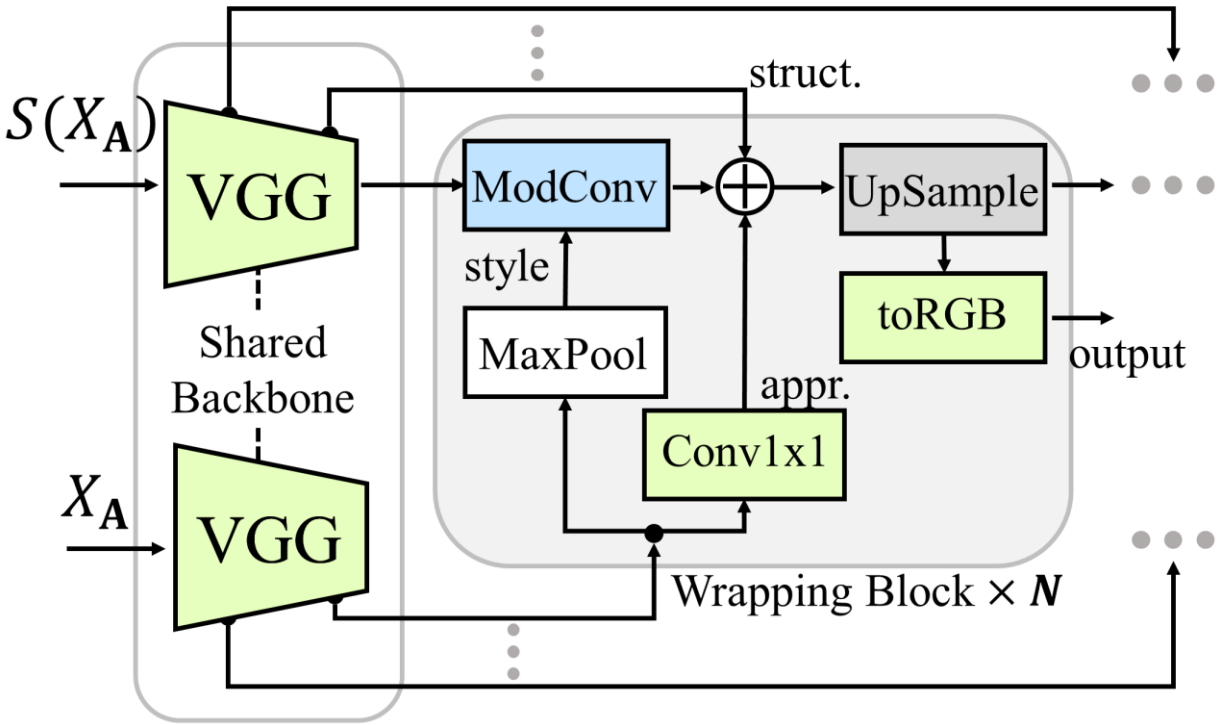
Step 1. Structure Disentanglement





Step 2. Appearance Wrapping





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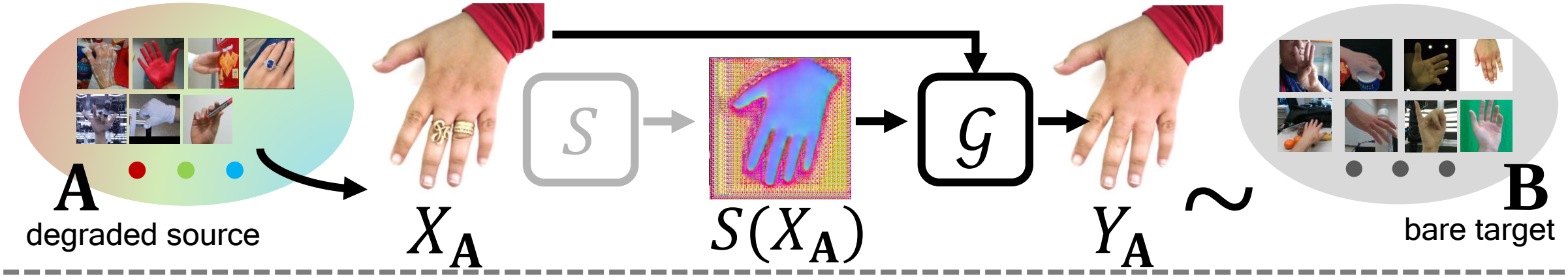

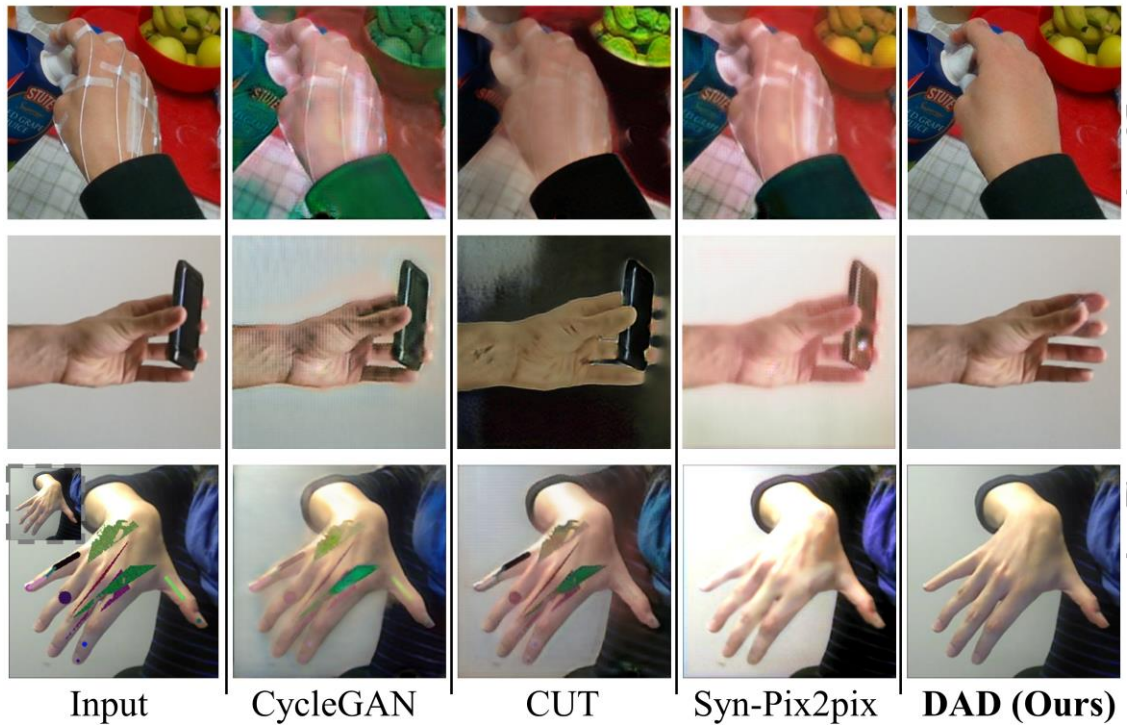

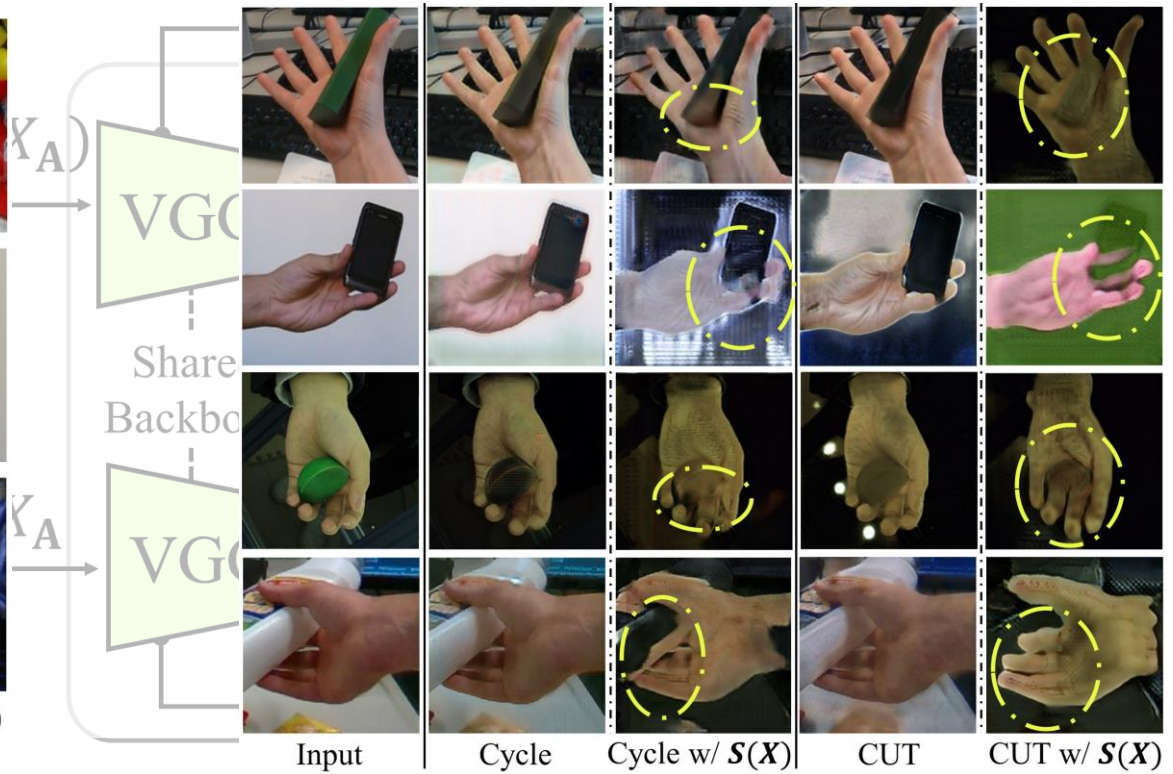

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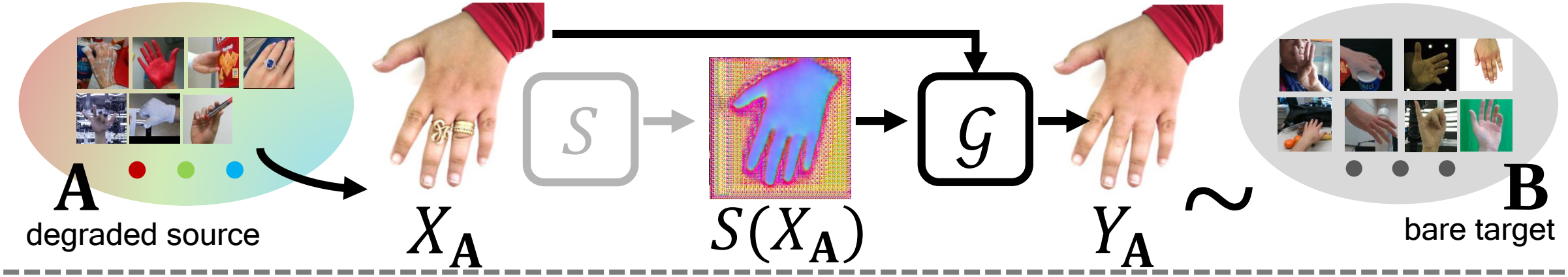

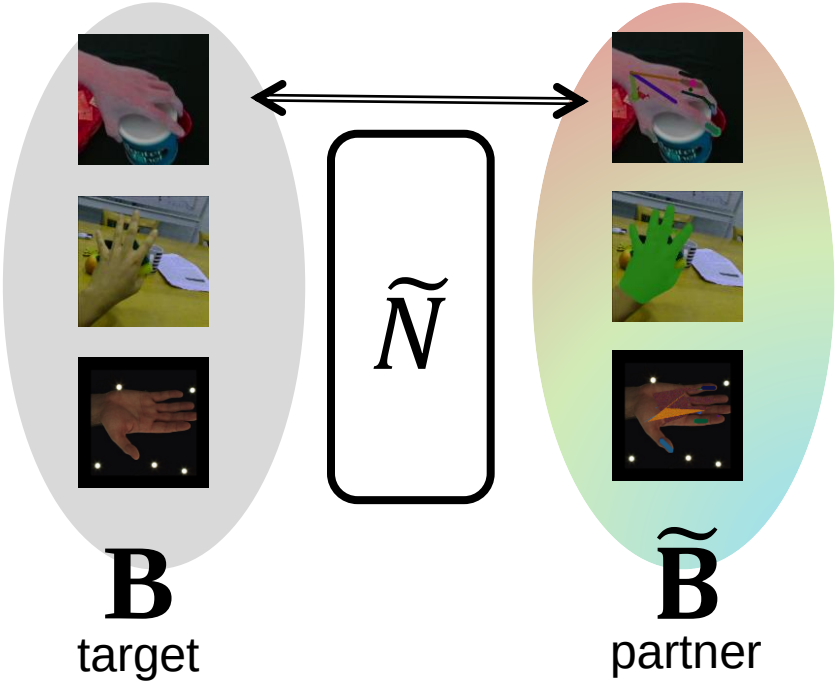

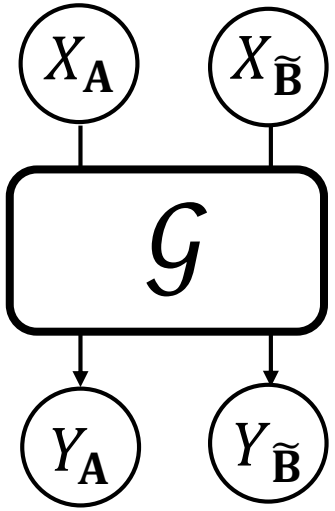

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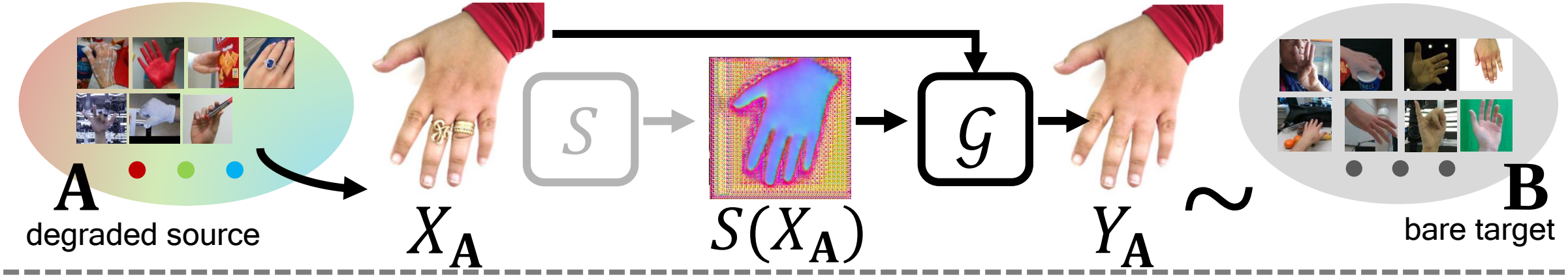

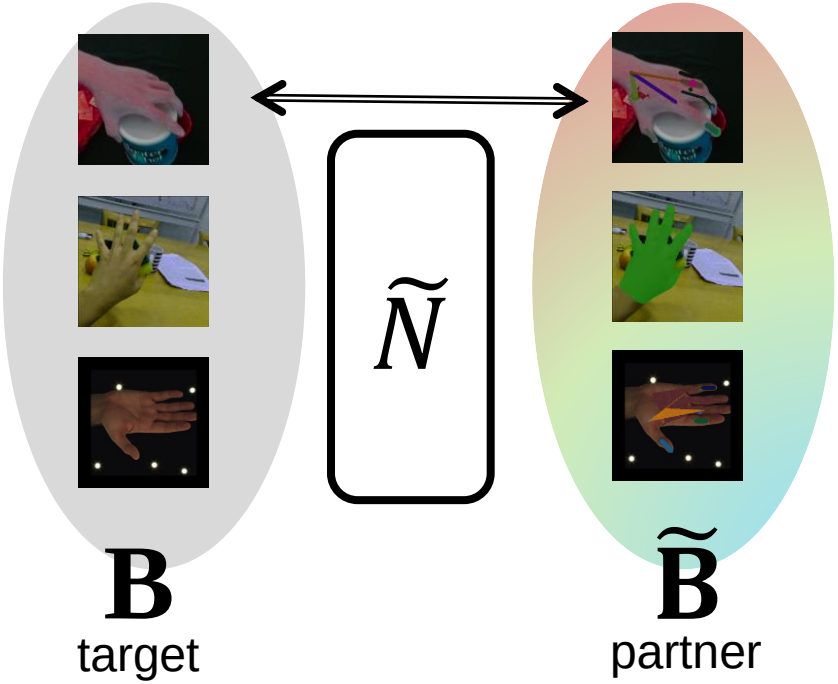

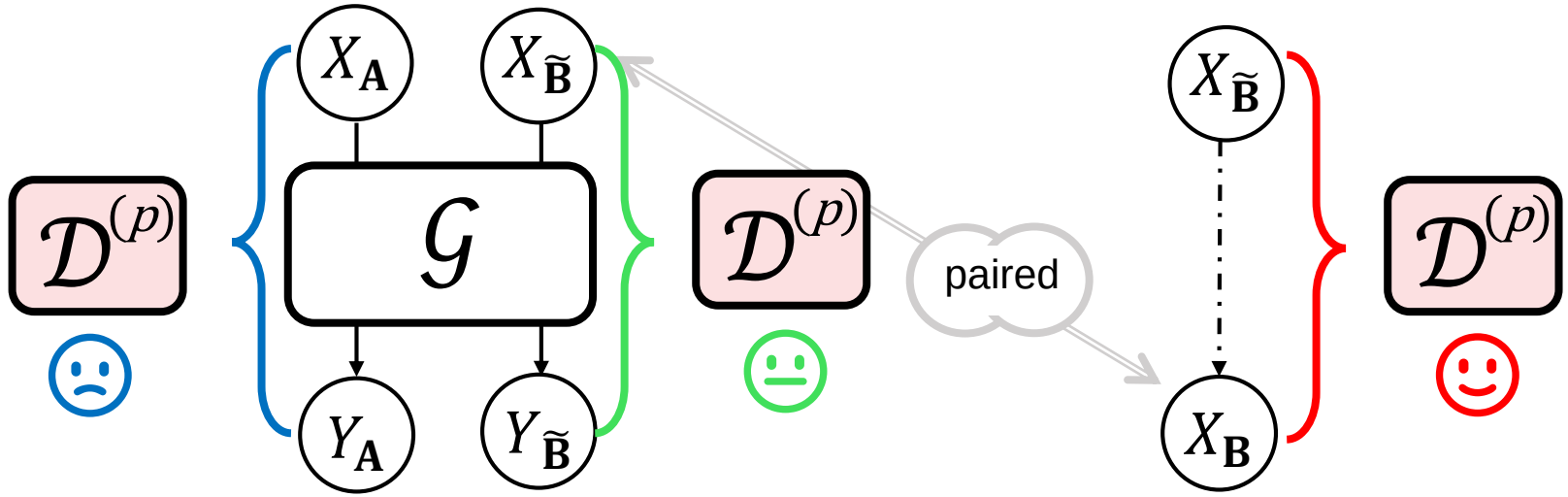

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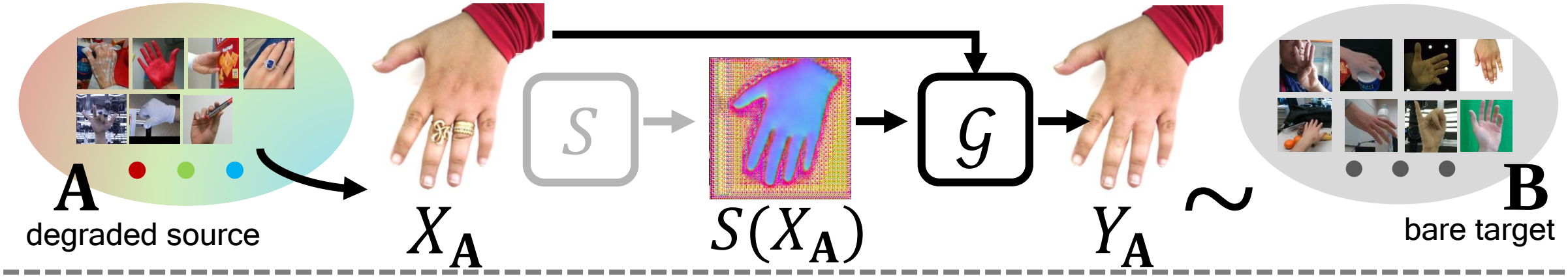

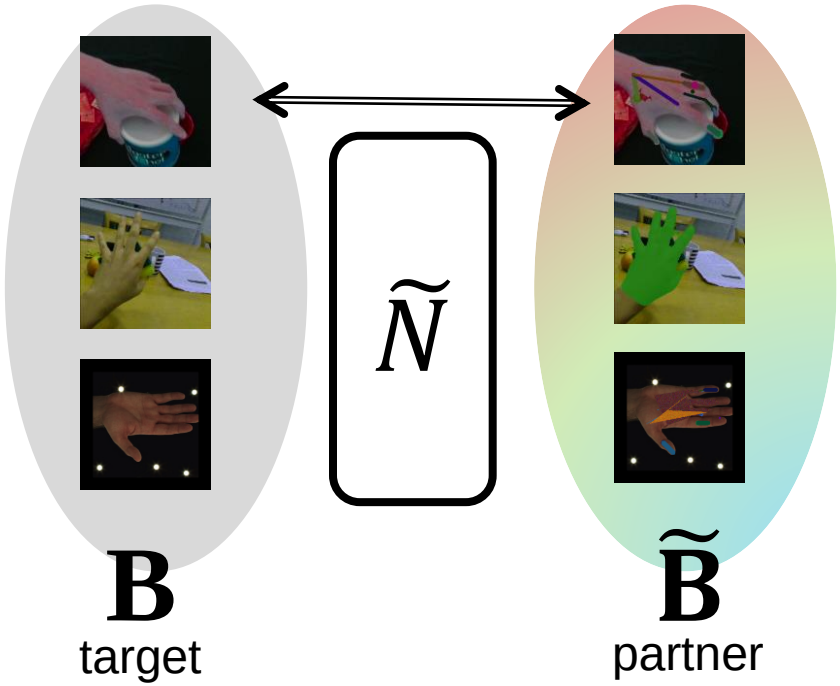

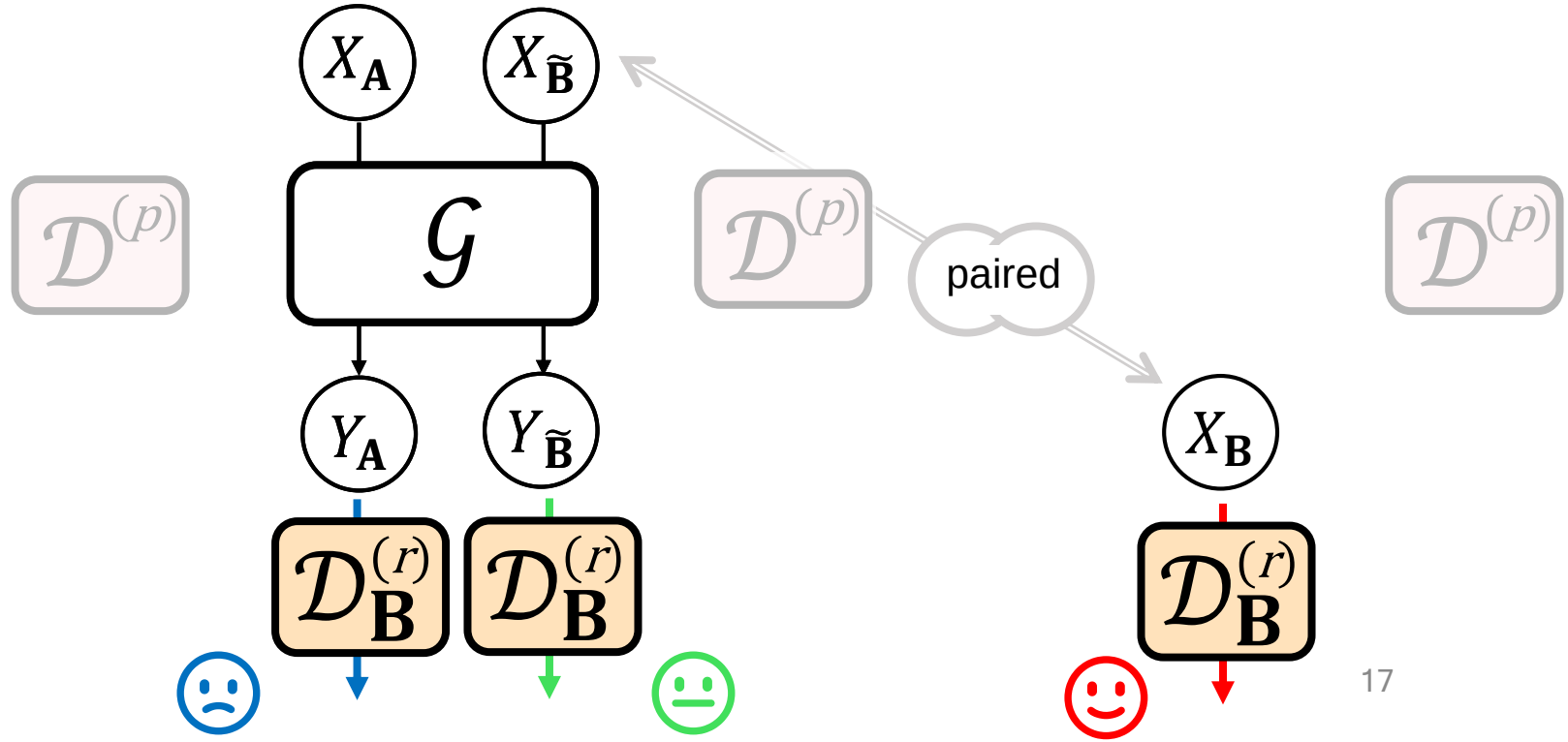

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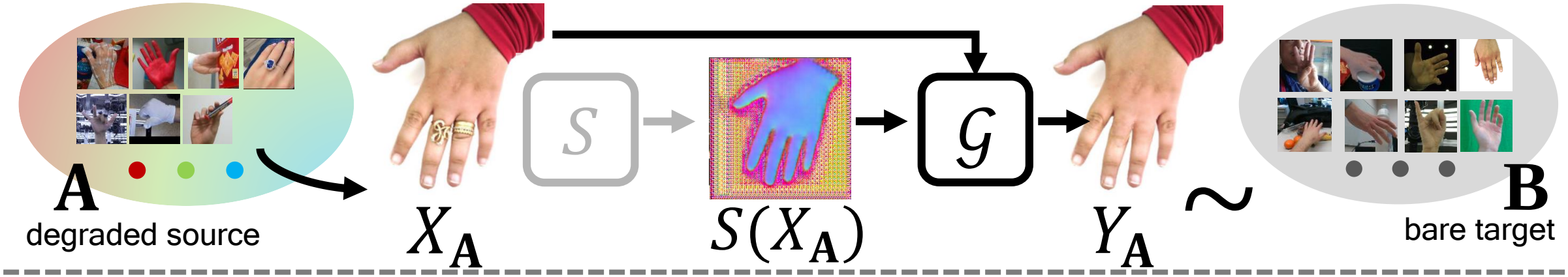
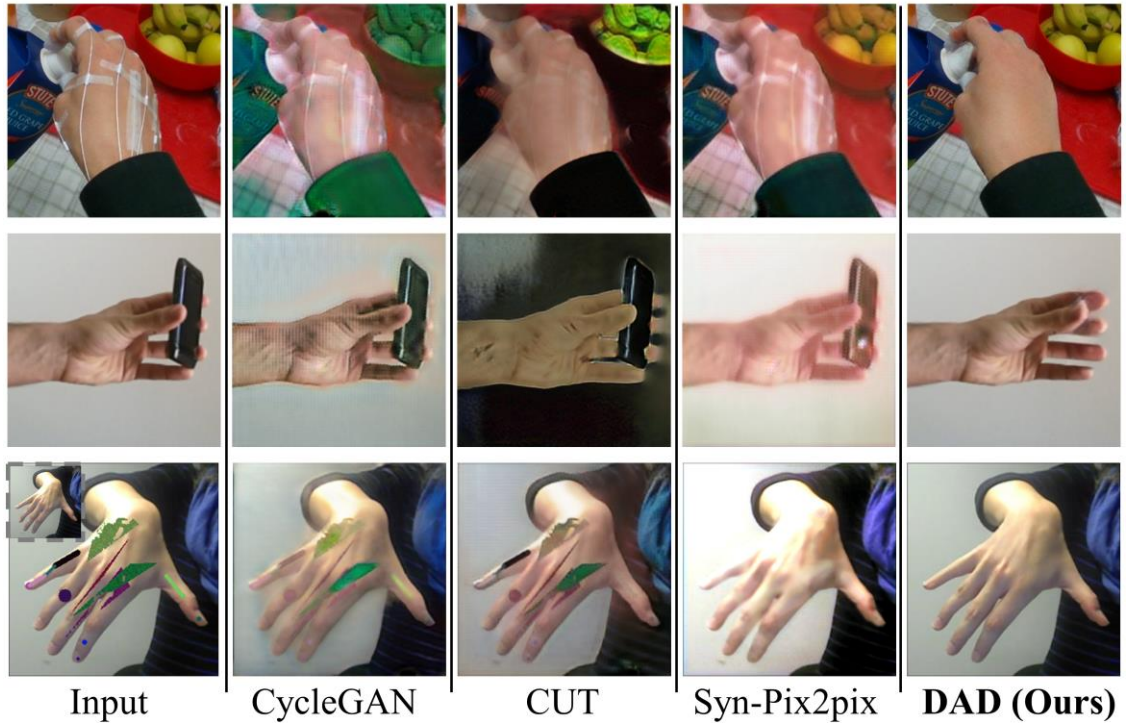
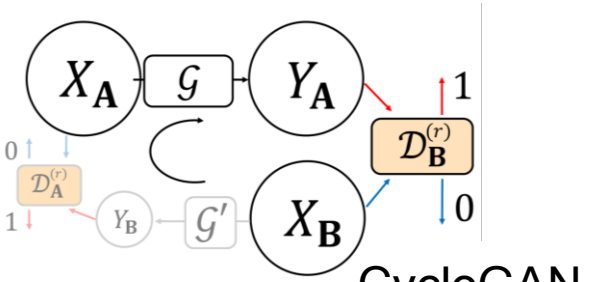
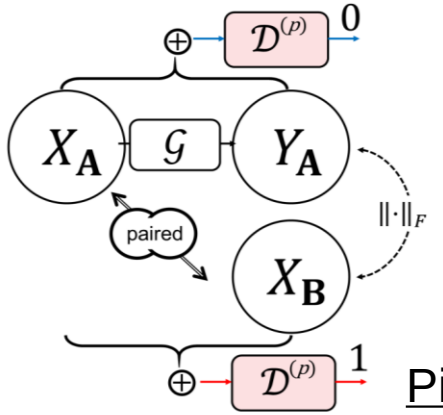


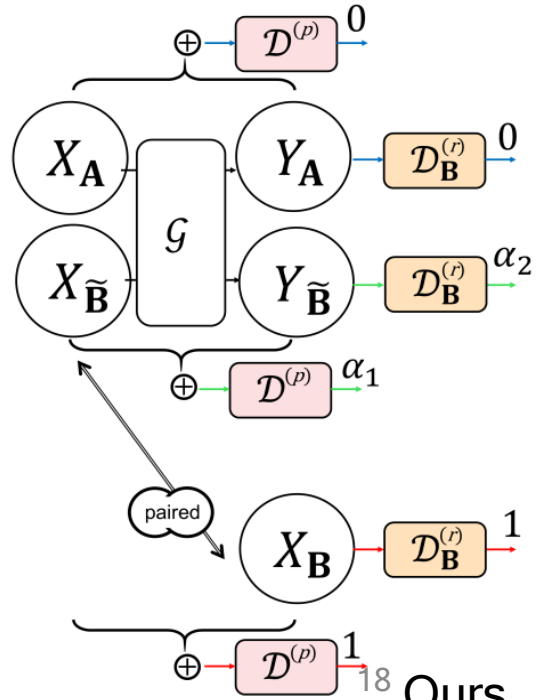




CycleGAN

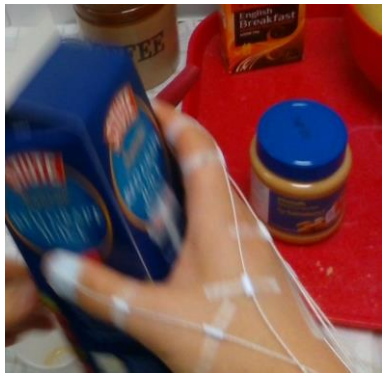


Pix2pix



Ours

Qualitative Results on Translation $\mathbf{A_1} \rightarrow \mathbf{B}$

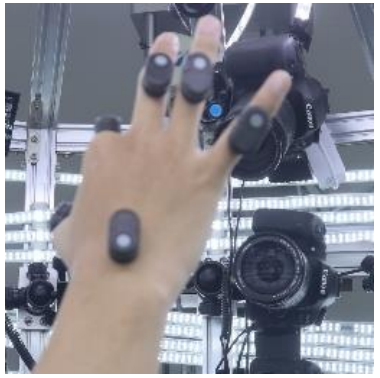





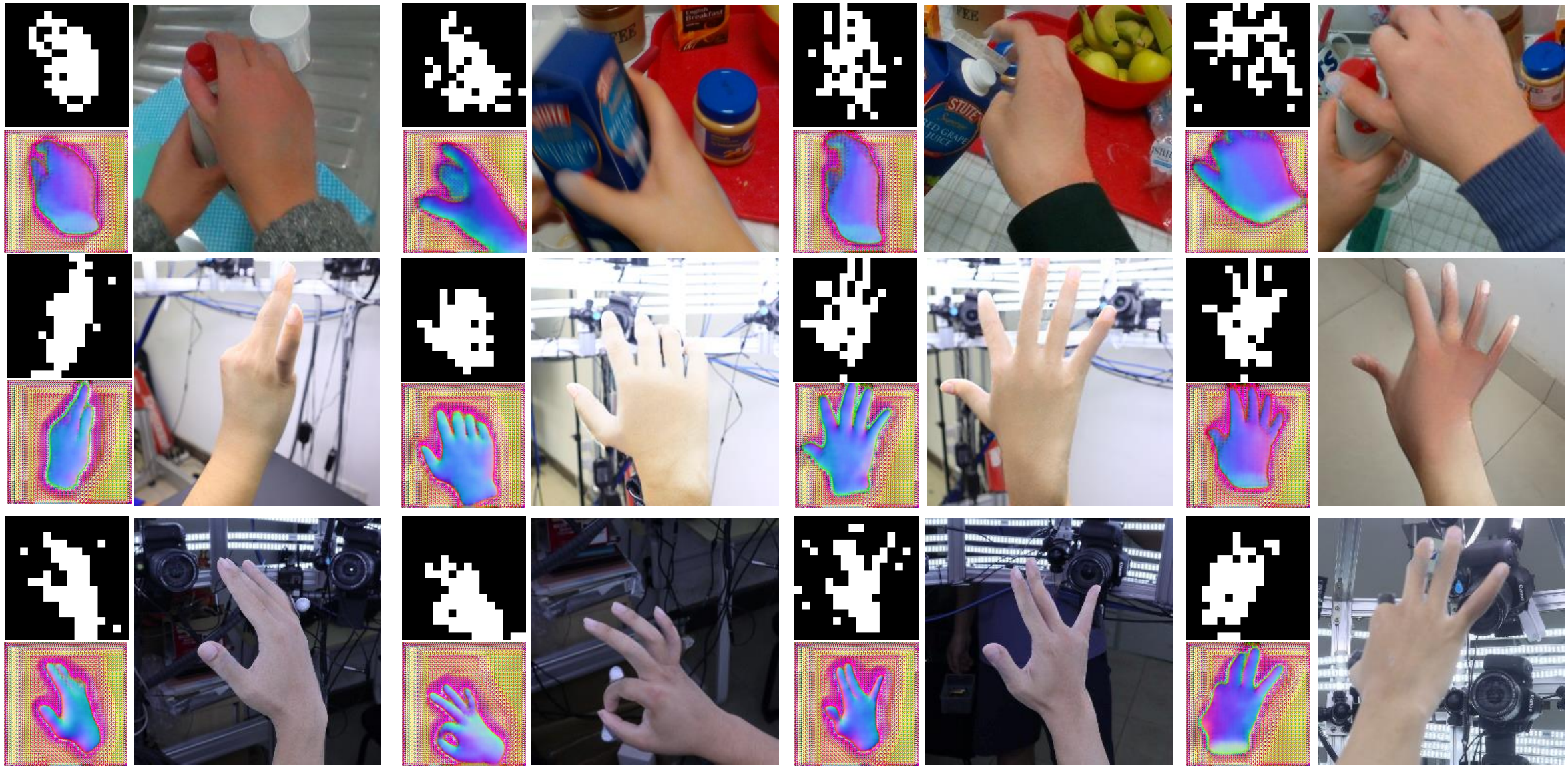






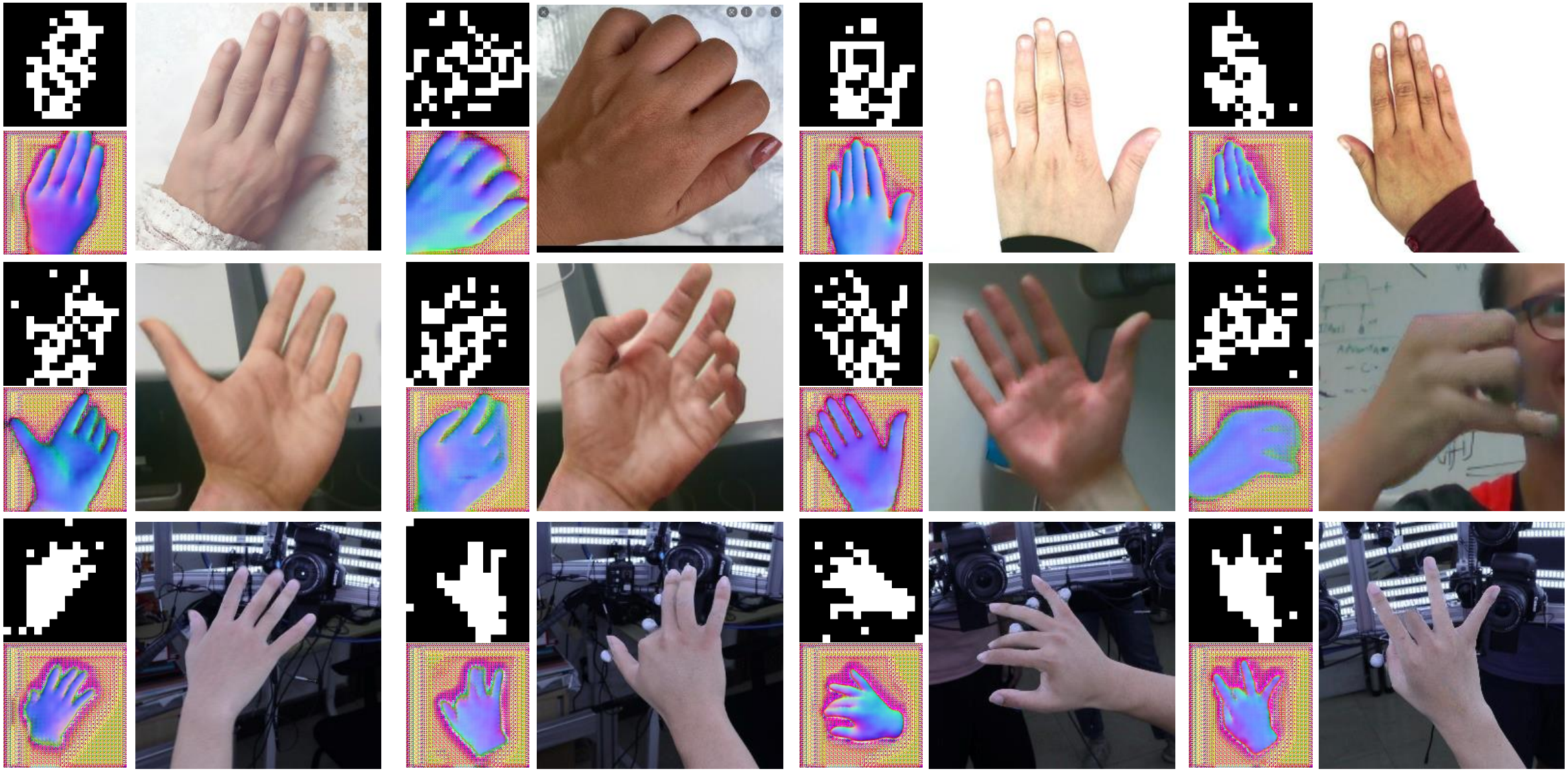


Qualitative Results on Translation $\mathbf{A_1} \rightarrow \mathbf{B}$



Qualitative Results on Translation $\mathbf{A_1} \rightarrow \mathbf{B}$

Qualitative Results on Translation $\mathbf{A_1 \rightarrow B}$

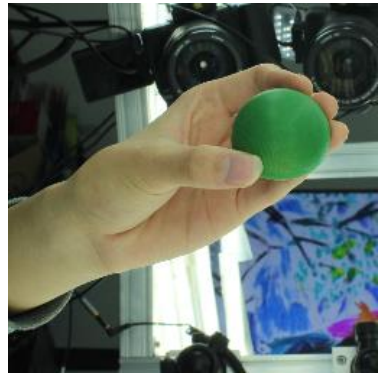


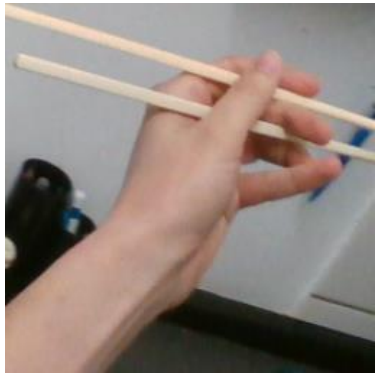
Qualitative Results on Translation $\mathbf{A_2 \rightarrow B}$

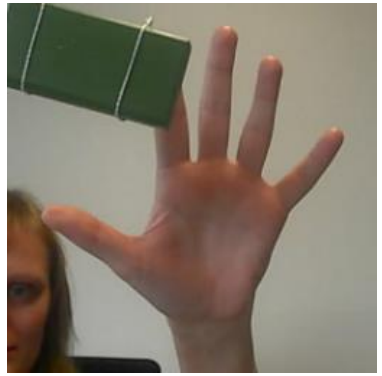




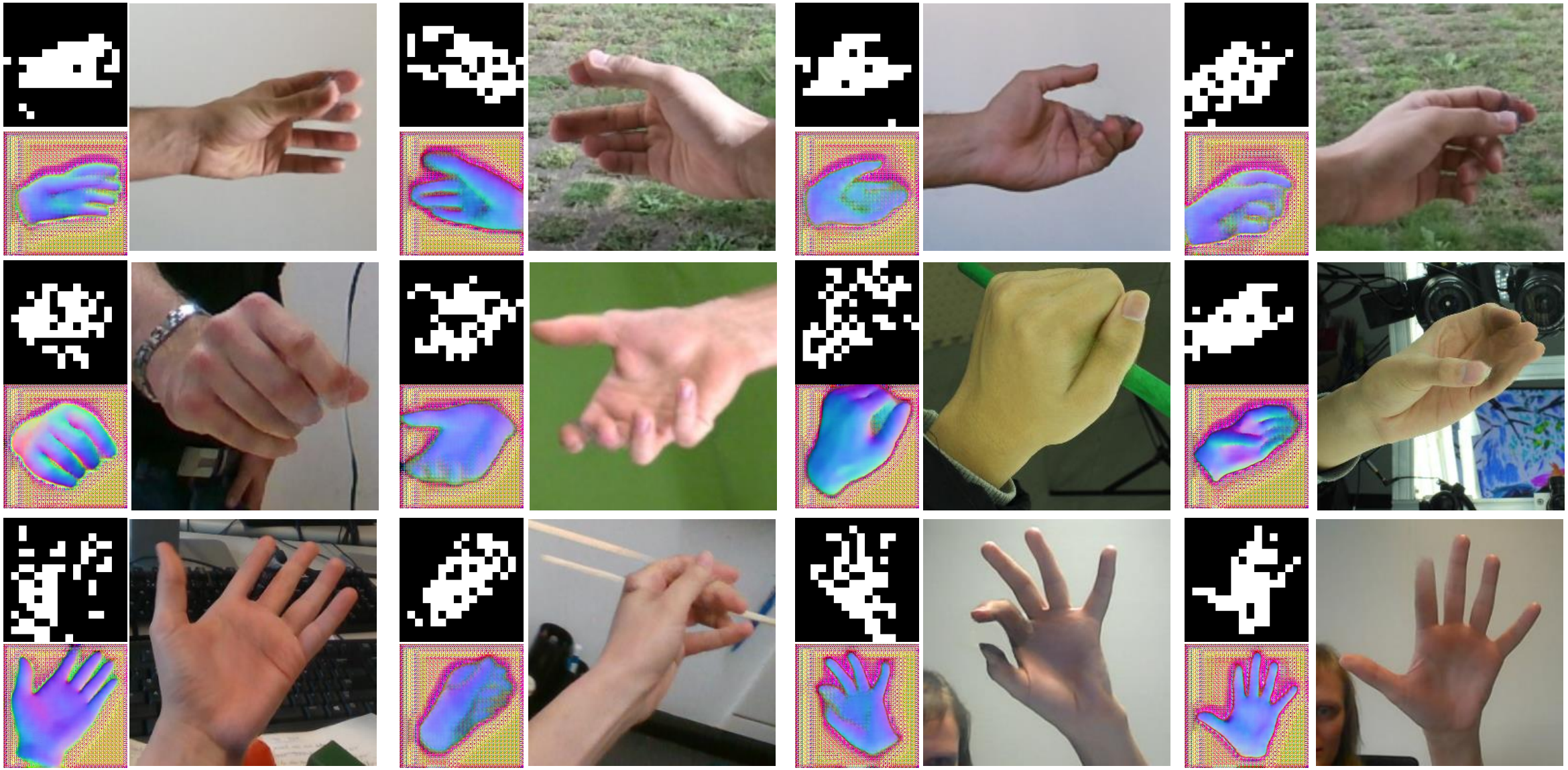






Qualitative Results on Translation $\mathbf{A_2 \rightarrow B}$

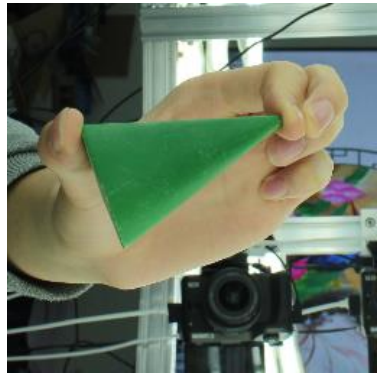


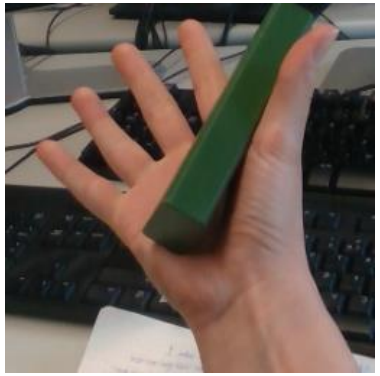
Qualitative Results on Translation $\mathbf{A_2 \rightarrow B}$

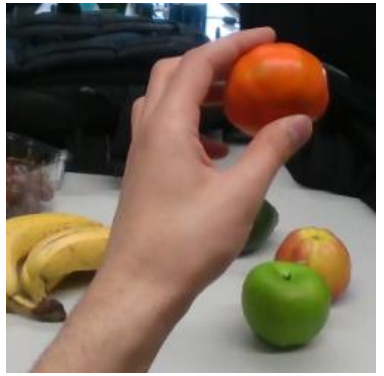




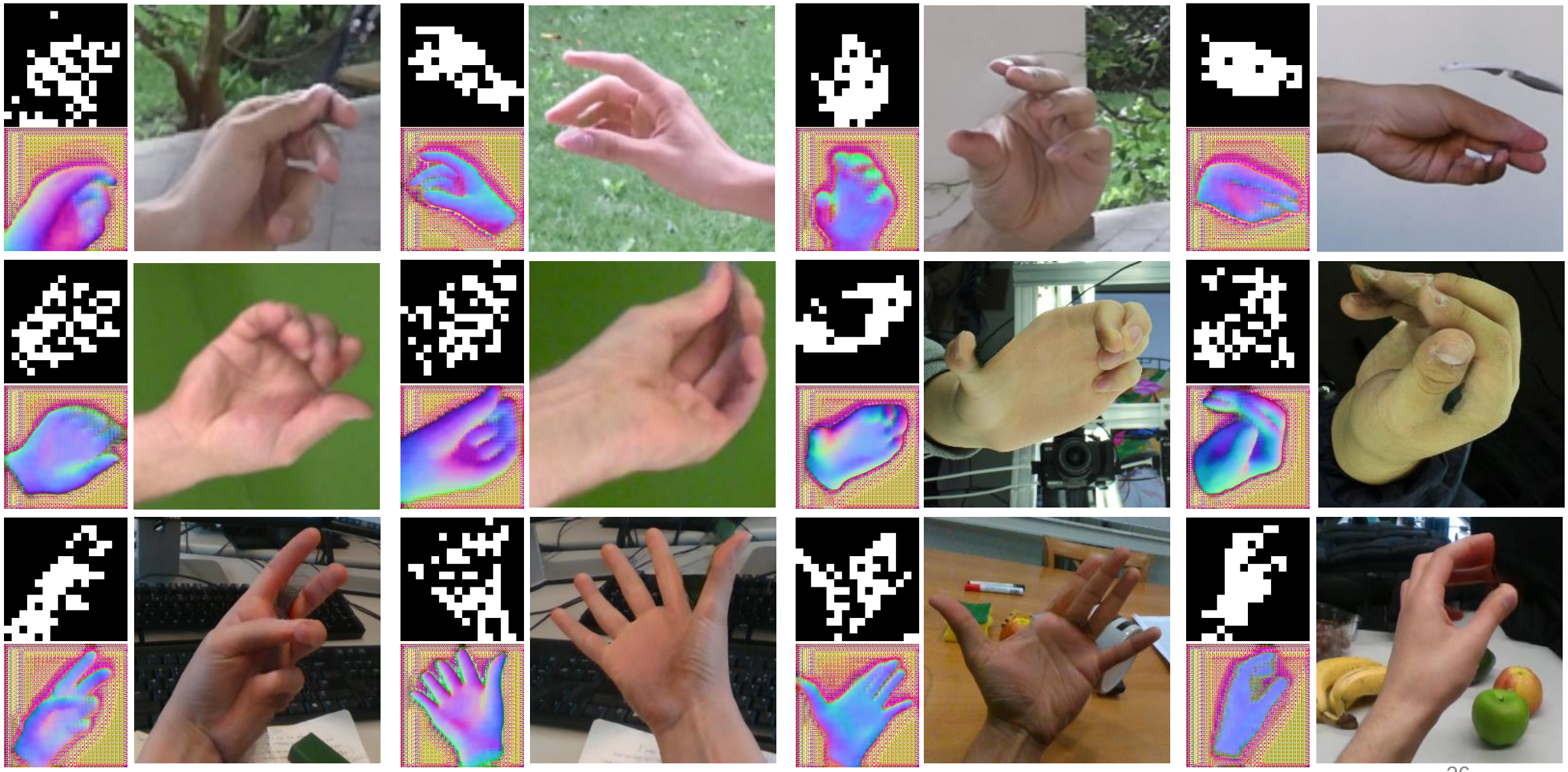






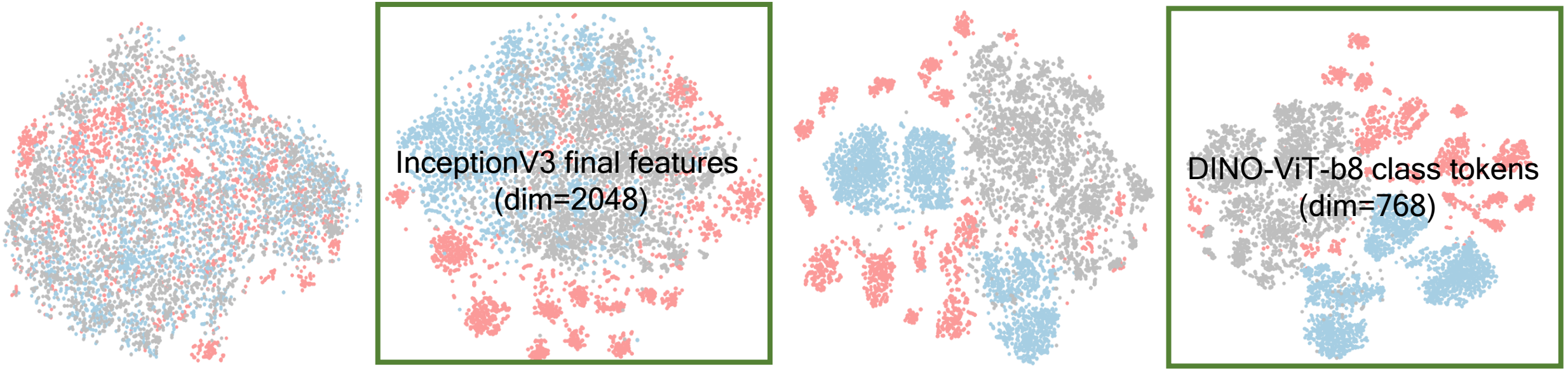
Qualitative Results on Translation $\mathbf{A_2 \rightarrow B}$



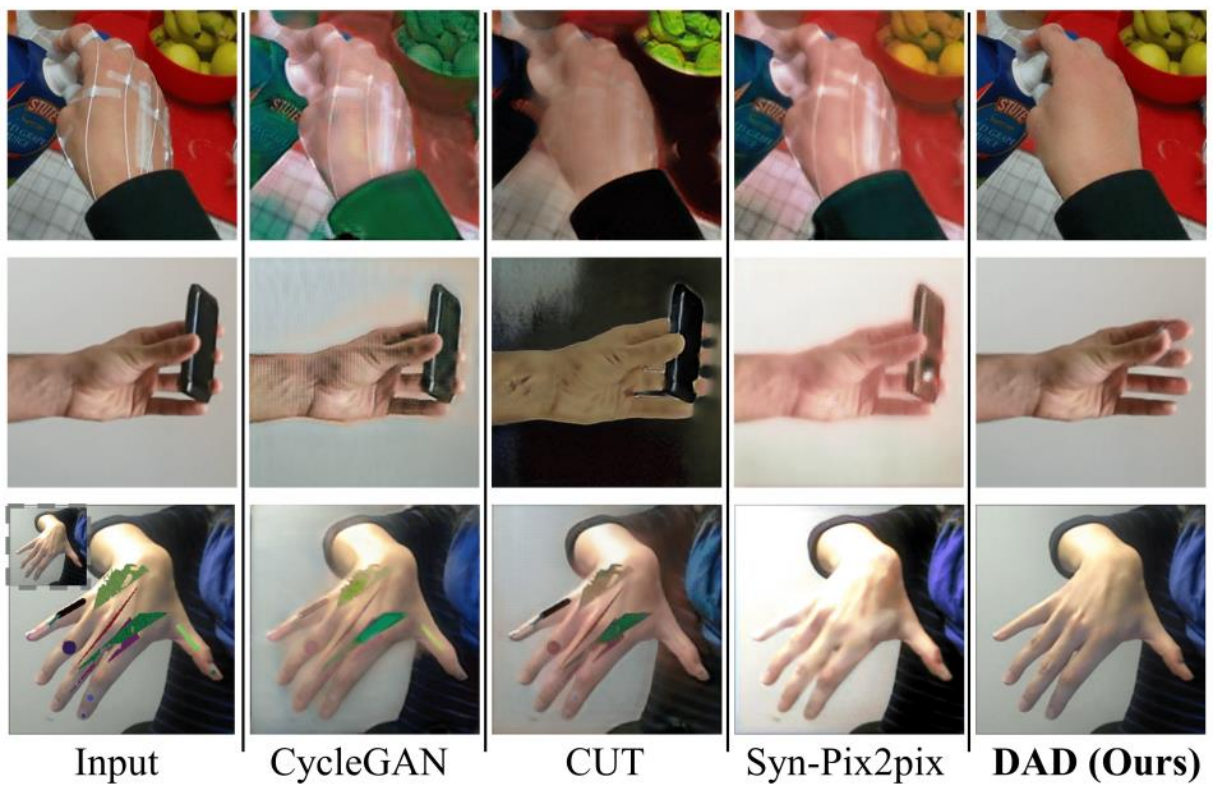
Quantitative Comparisons

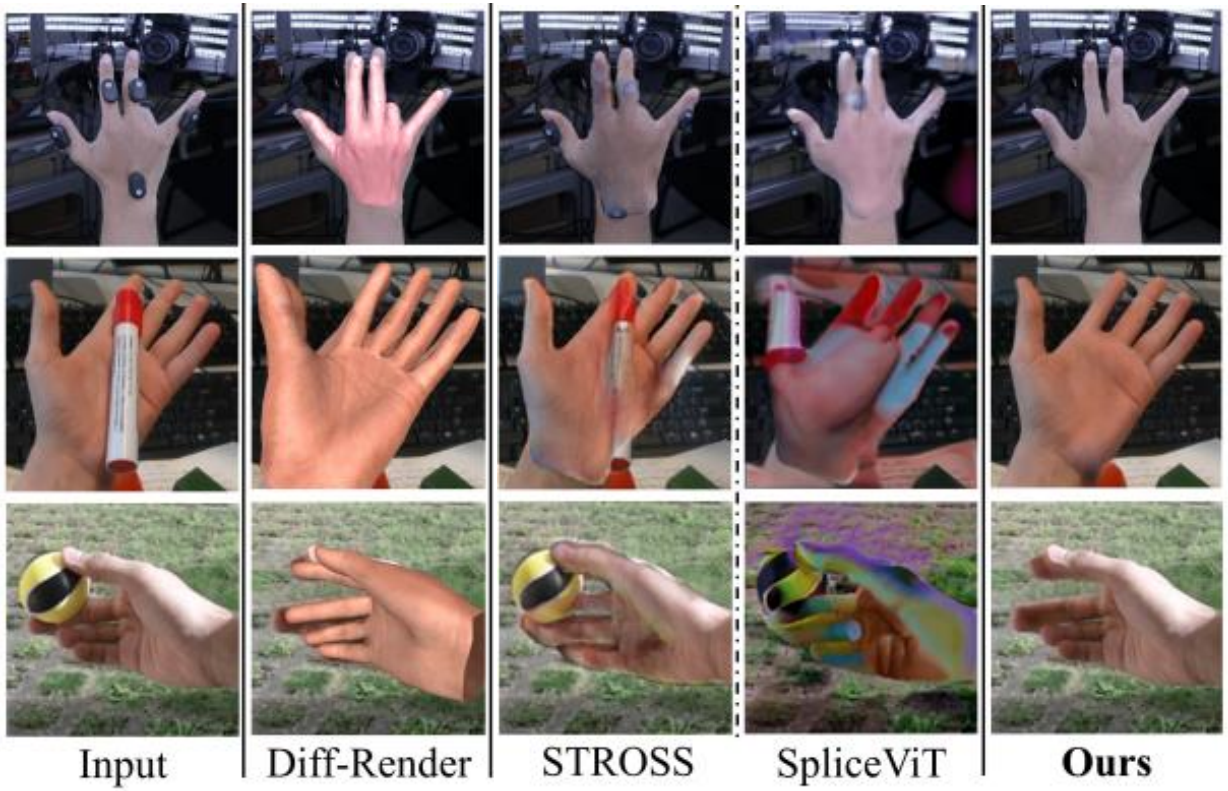
Tasks	$A_1 \rightarrow B$				$A_2 \rightarrow B$			
Metrics	$FID_i \downarrow$	$KID_i(*100) \downarrow$	$FID_v \downarrow$	$KID_v \downarrow$	$FID_i \downarrow$	$KID_i(*100) \downarrow$	$FID_v \downarrow$	$KID_v \downarrow$
CycleGAN [91]	76.39	4.46 ± 0.176	1266.17	32.02 ± 0.994	65.12	4.44 ± 0.196	1021.14	27.13 ± 0.948
GANerated [52]	76.97	4.72 ± 0.153	1220.53	31.72 ± 0.907	68.50	5.05 ± 0.199	985.82	26.75 ± 0.987
H-GAN [56]	93.02	6.53 ± 0.209	1488.32	37.85 ± 1.061	62.94	4.12 ± 0.197	876.94	24.61 ± 0.816
UAG [5]	87.80	5.90 ± 0.177	1375.55	35.67 ± 0.949	70.98	5.35 ± 0.210	1069.45	28.31 ± 0.926
CUT [57]	78.02	5.54 ± 0.192	1230.67	33.34 ± 1.015	58.88	3.73 ± 0.160	749.22	20.02 ± 0.826
Ours	**60.37**	$\mathbf{3.45 \pm 0.236}$	**994.67**	$\mathbf{28.67 \pm 0.916}$	**41.53**	$\mathbf{3.37 \pm 0.154}$	**673.43**	$\mathbf{15.72 \pm 1.209}$

data in $\mathbf{A_1}$ data in $\mathbf{A_2}$ data in $\mathbf{B}$



Qualitative Comparisons





Conclusion

- This work pioneers a semi-supervised image-to-image translation to recover the hand appearance that was originally degraded during the marker-based MoCap process.
- The prior-based sketcher can robustly disentangle the bare structure maps from degraded hand images.
- The DAD is more efficient than unsupervised schemes, and more generalizable than a supervised scheme trained with synthetic degradation.

Project Page