Data-Scarce Animal Face Alignment via Bi-Directional Cross-Species Knowledge Transfer

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Animal face alignment

- Detect facial landmarks
- Large significance
  - Better understanding animals
  - Promote their health
  - Less expensive to examinations

- It remains largely **unexplored**!

- ✓ Facial expression analysis
- ✓ Animal pain detection
- ✓ Facial tracking

Challenges

- Large intra- and inter- species variations
- Lack large-scale annotated data!!

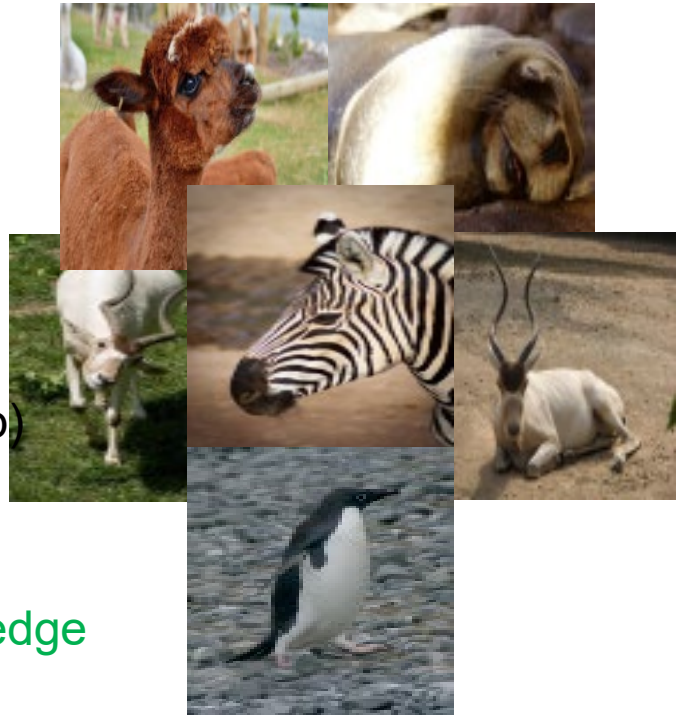
- 300W
- AFLW
- Menpo
- …

- AnimalWeb

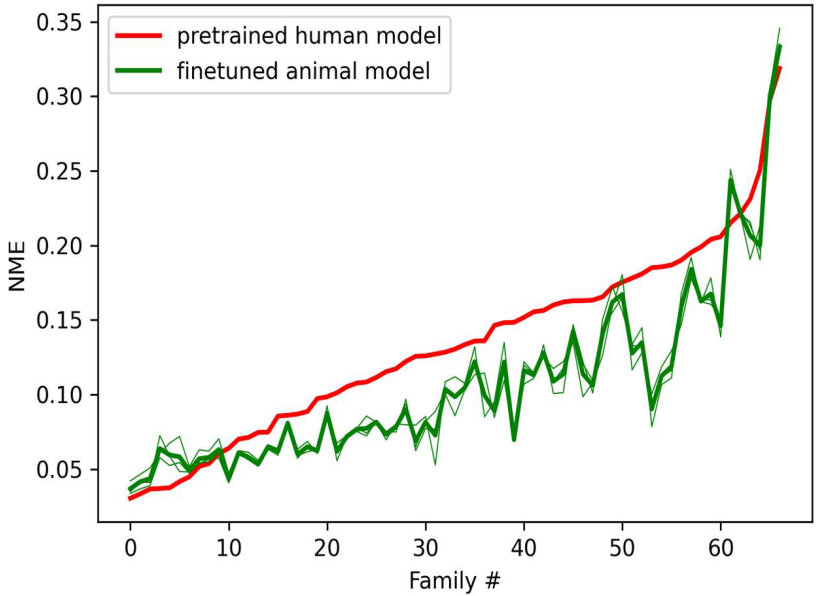
- Our focus: **data-scarce** animal face alignment

Challenges

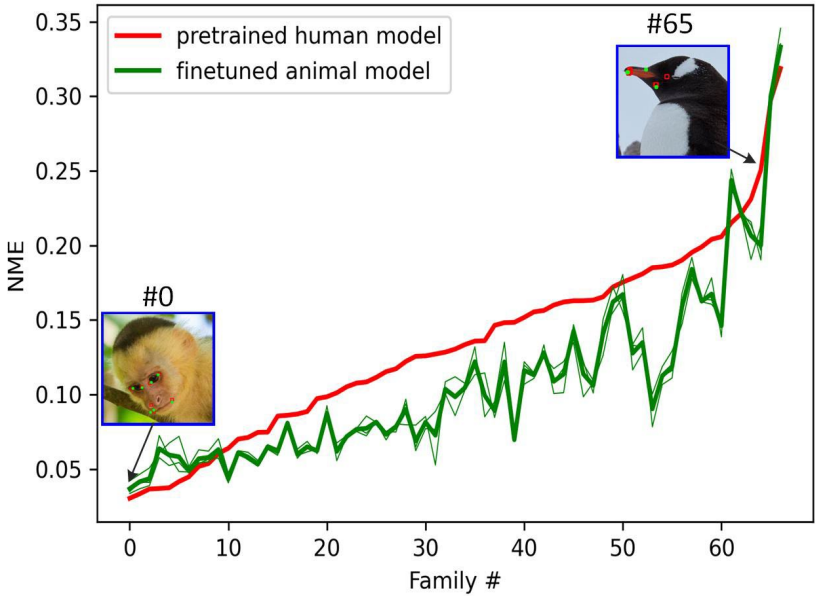
- Large intra- and inter- species variations
- Lack large-scale annotated data!!
- Existing solutions
  - Finetuning human face alignment model
  - Animal-specific face alignment (horse, sheep)
  - Utilize auxiliary information
- Our solution (Meta-CSKT)
  - Leverage bi-directional cross-species knowledge transfer



Motivation


pretrained human model
finetuned animal model
NME
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
10
20
30
40
50
60
Family #

Motivation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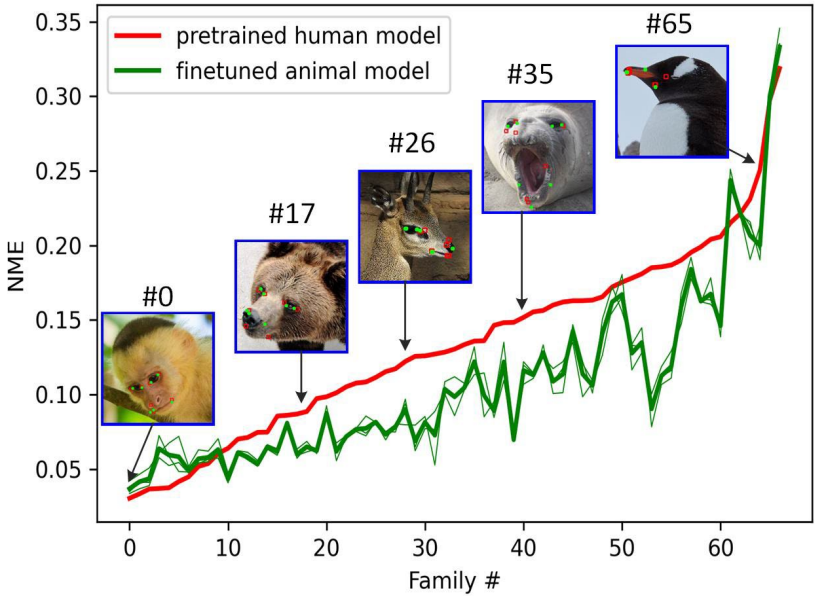
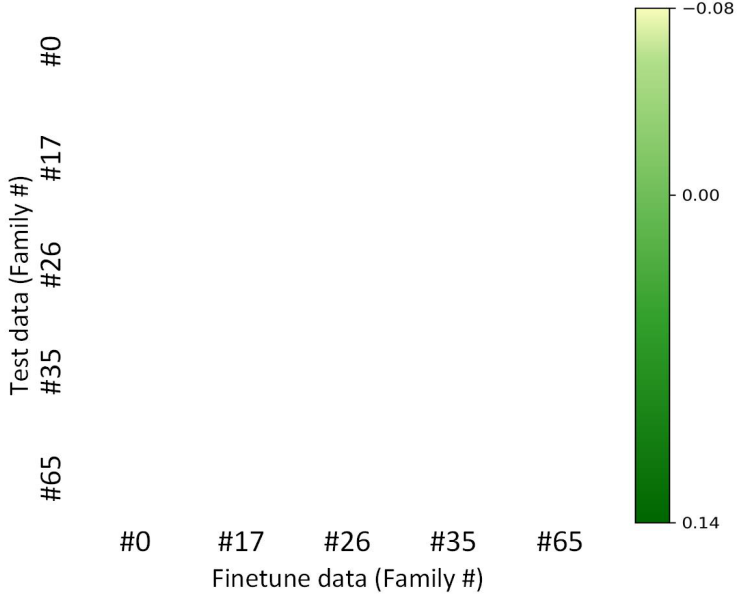
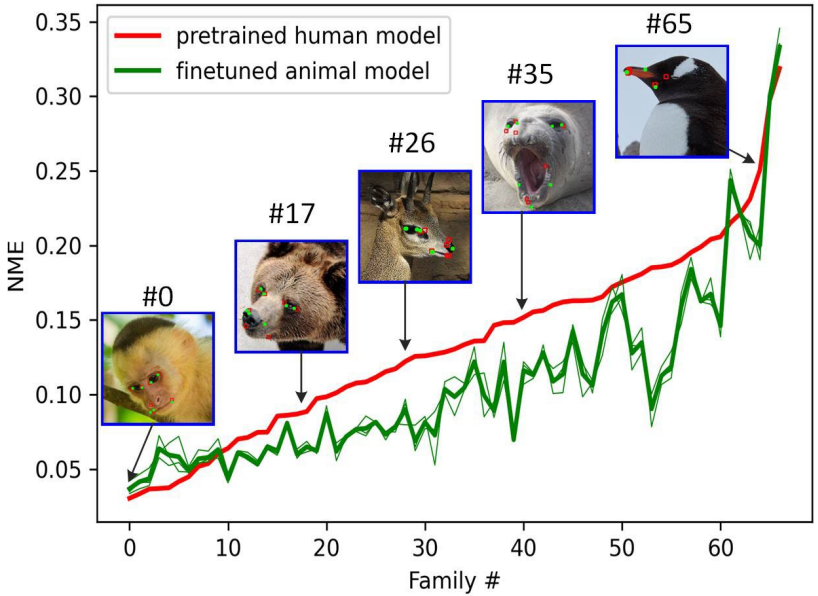


NME Difference Confusion Matrix



SUSTech Southern University of Science and Technology

Motivation


pretrained human model
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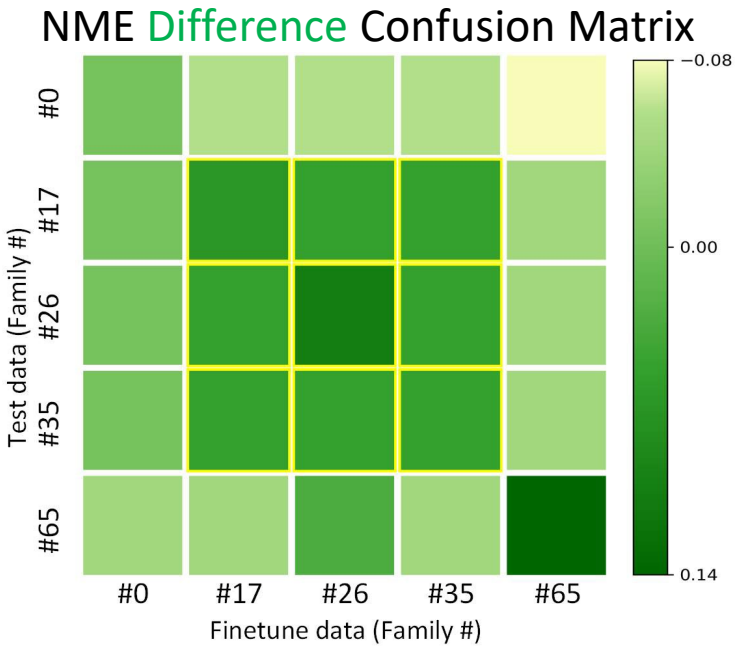
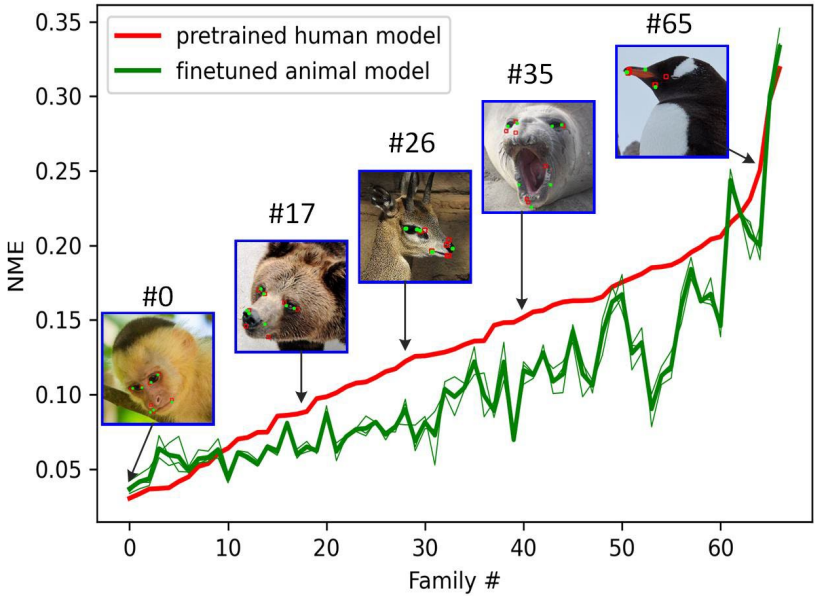
NME
Family #
#0
#17
#26
#35
#65


NME Difference Confusion Matrix
Test data (Family #)
Finetune data (Family #)
#0
#17
#26
#35
#65
0.08
0.00
0.14

Motivation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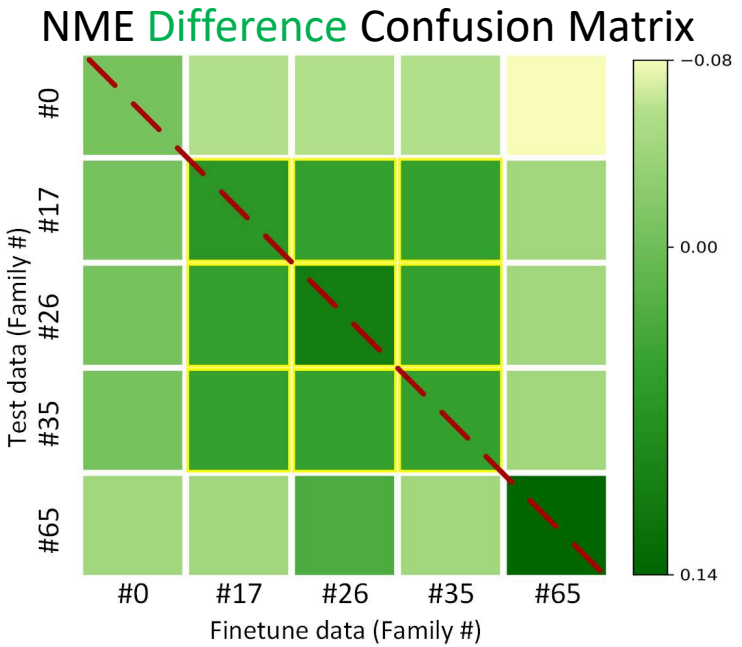
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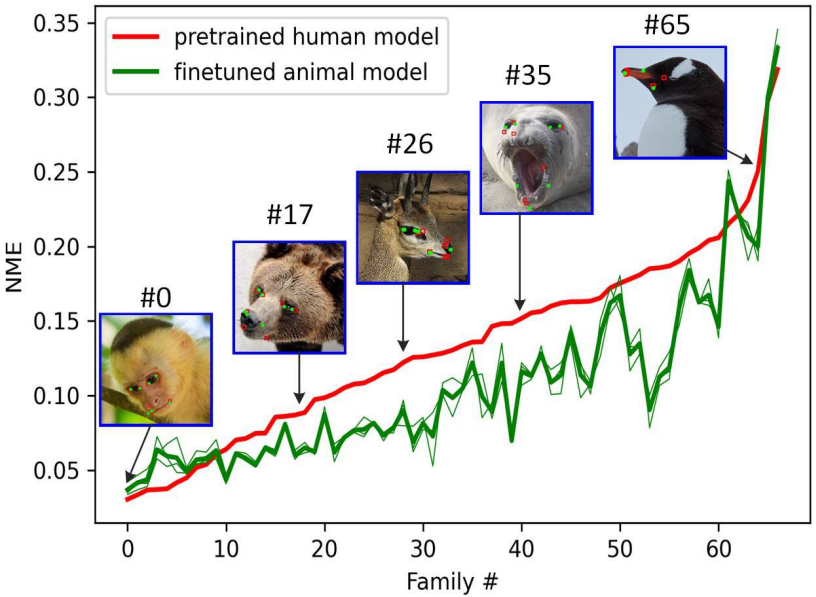
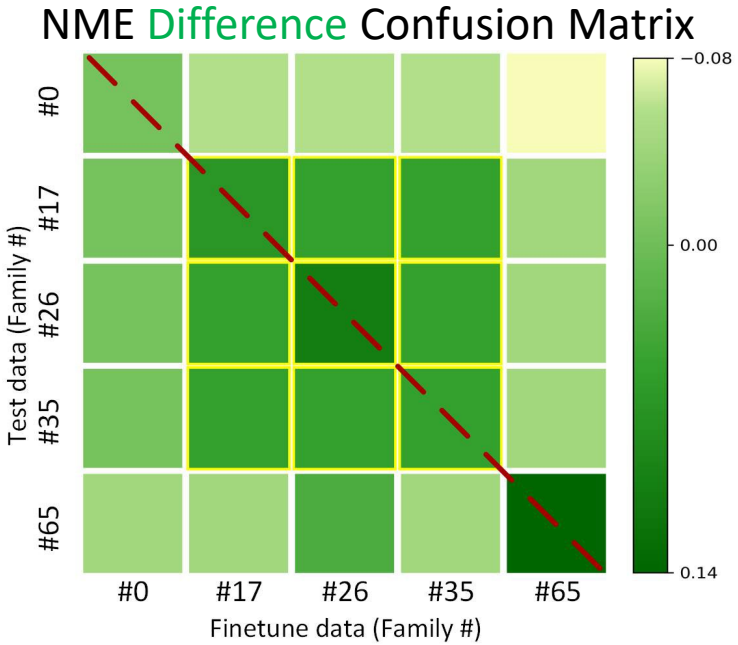
Motivation

Knowledge sharing among animal species, which provides a fundamental premise for Meta-CSKT!!





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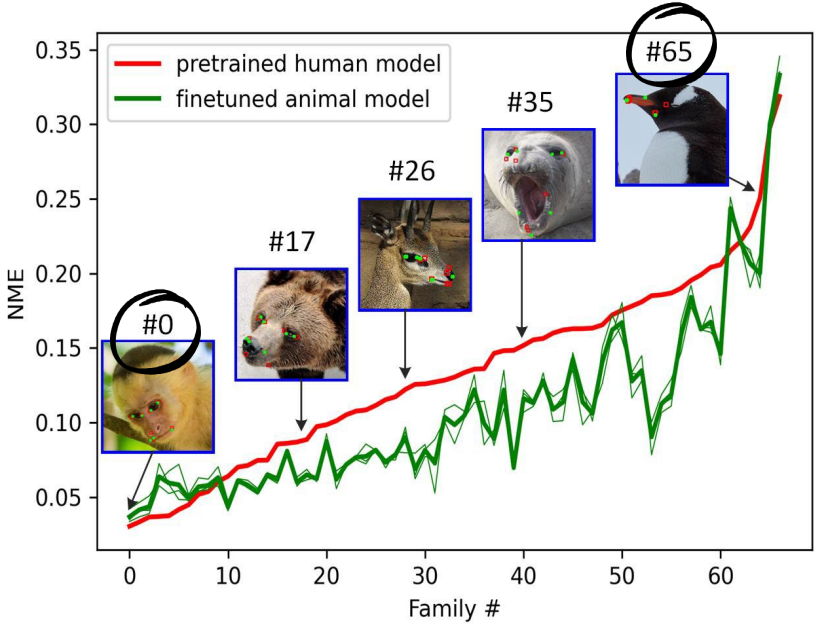
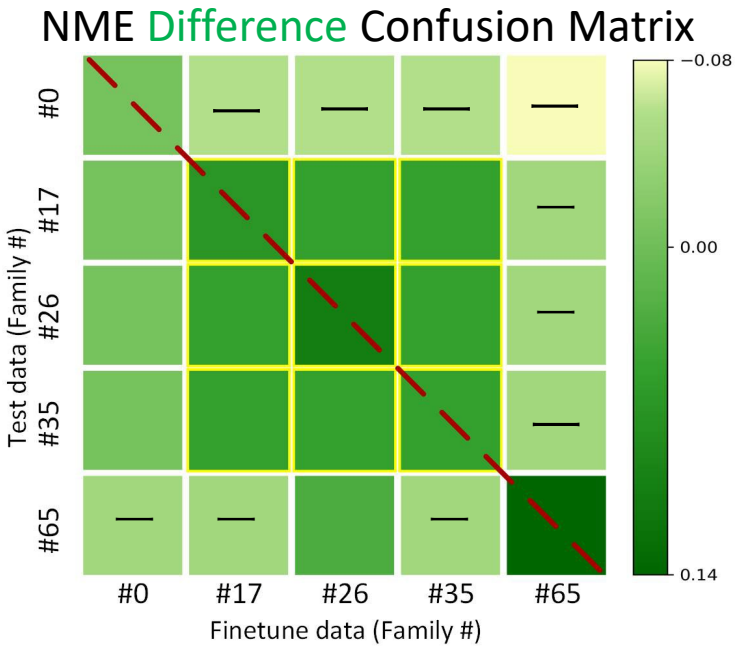




Meta-CSKT

Large-scale unlabeled animals

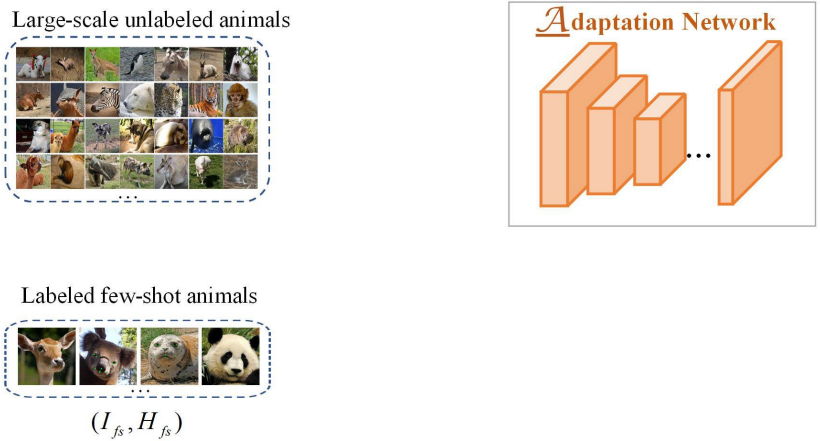
Labeled few-shot animals

(I_{fs}, H_{fs})

Labeled data is SCARCE!

Data flow
Mine positive examples
Discard hard negatives
Bi-directional cross-species knowledge transfer

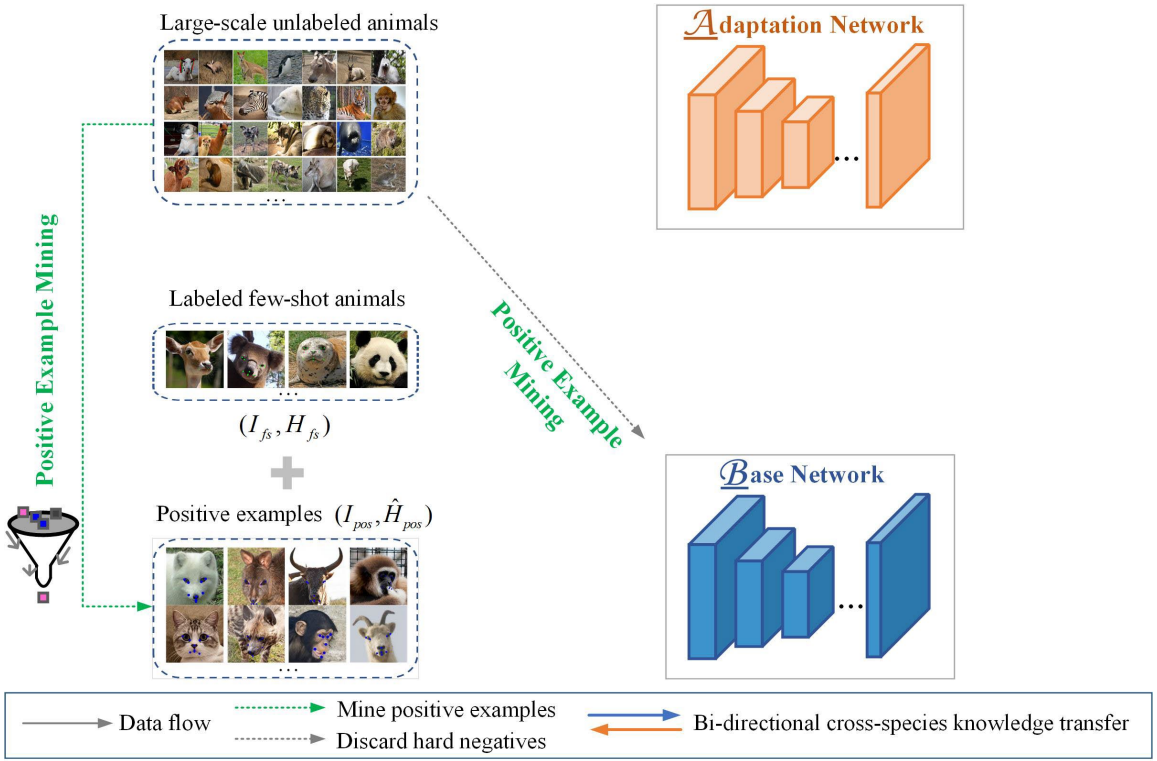
Meta-CSKT



Labeled data is SCARCE!

Two complement networks

Meta-CSKT



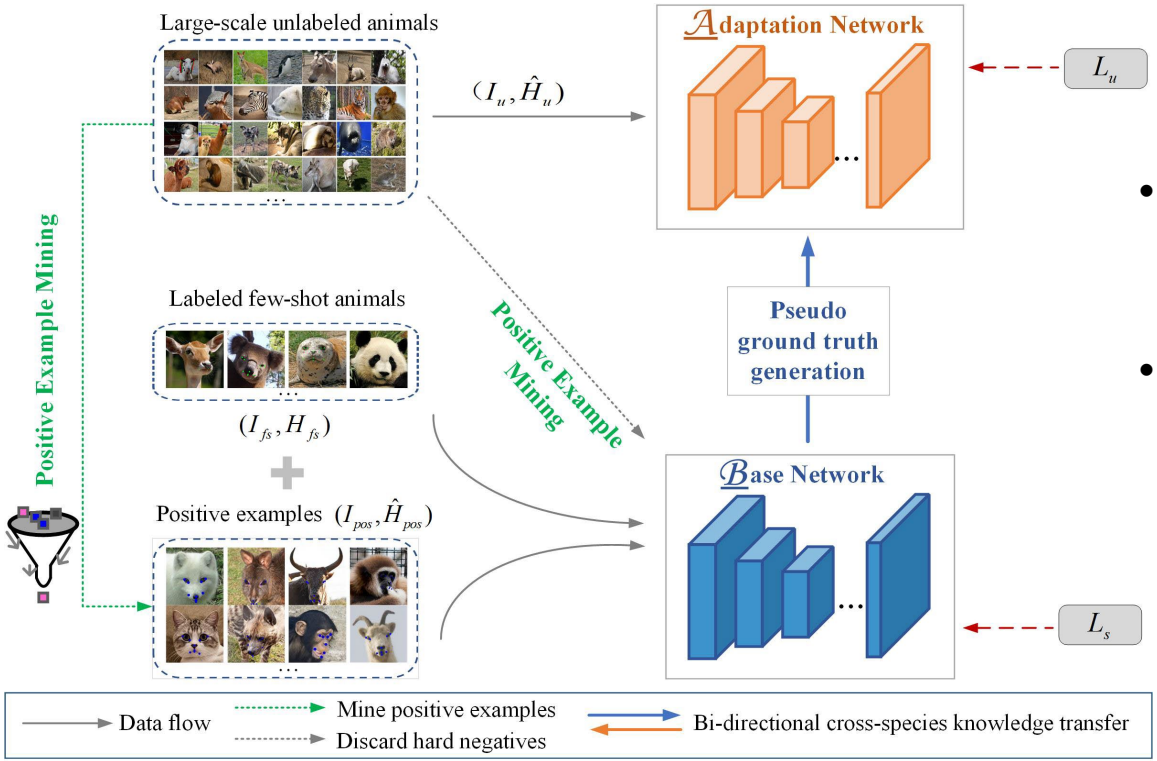
Labeled data is SCARCE!

Two complement networks

Positive example mining :

- Augment labeled data
- Purify unlabeled data

Meta-CSKT



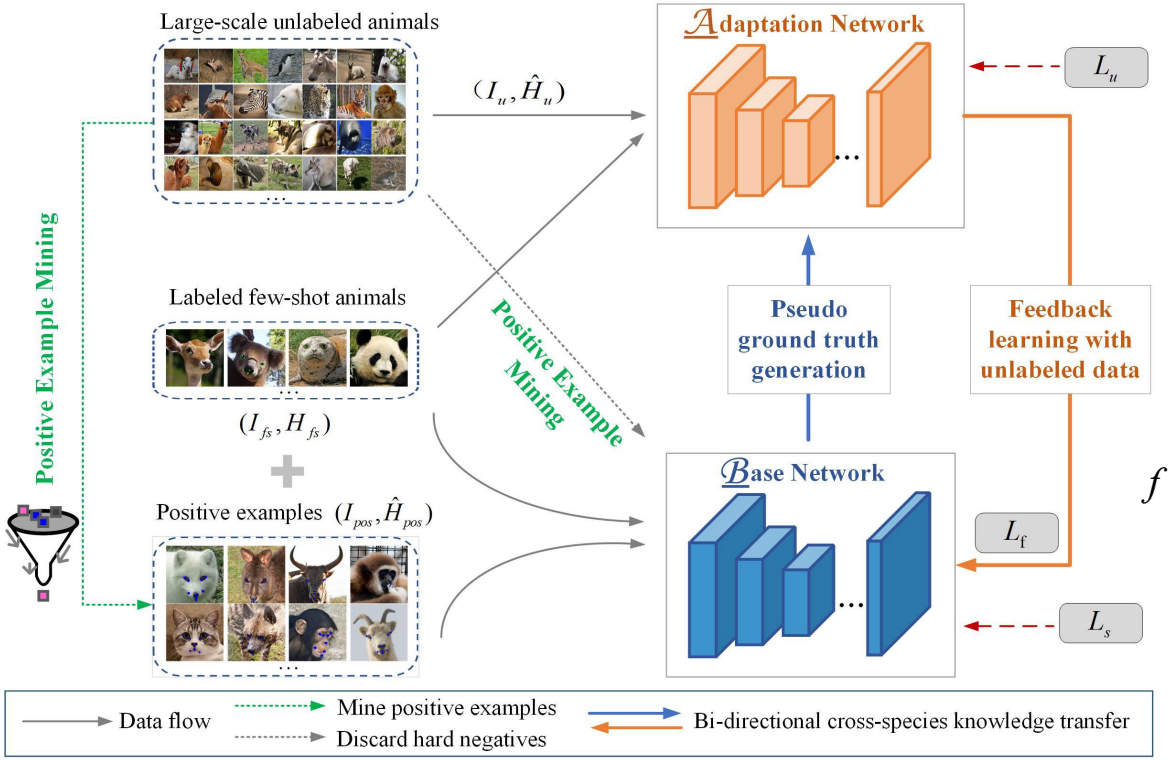
Adaptation network:

- $\mathcal{L}_u = \left\| \hat{H}_u - \mathcal{A}(I_u; \theta_{\mathcal{A}}) \right\|^2$

Base network (1/2):

- $\mathcal{L}_s = \left\| H_{fs} - \mathcal{B}(I_{fs}; \theta_{\mathcal{B}}) \right\|^2 + \left\| \mathcal{A}(I_{pos}; \theta_{\mathcal{A}}) - \mathcal{B}(I_{pos}; \theta_{\mathcal{B}}) \right\|^2$

Meta-CSKT



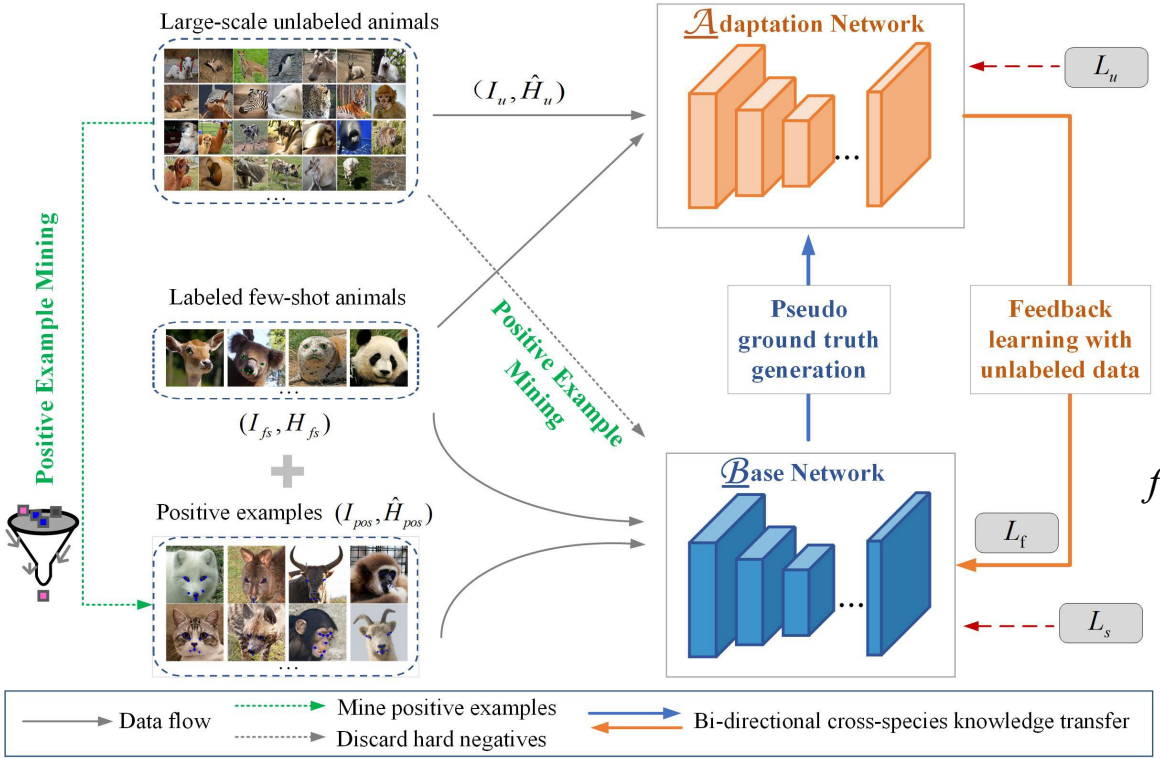
Base network (2/2):

Feedback loss

- $\mathcal{L}_f = \boxed{f} \cdot \left\| \hat{H}_u - \mathcal{B}(I_u; \theta_{\mathcal{B}}) \right\|^2$

$$f = \eta_{\mathcal{A}} \cdot (\nabla_{\theta_{\mathcal{A}}^{(t+1)}} \mathrm{MSE}(H_{fs}, \mathcal{A}(I_{fs}; \theta_{\mathcal{A}}^{(t+1)}))^{\mathrm{T}} \cdot \nabla_{\theta_{\mathcal{A}}} \mathrm{MSE}(\hat{H}_u, \mathcal{A}(I_u; \theta_{\mathcal{A}}^{(t)})))$$

Meta-CSKT



Base network (2/2):

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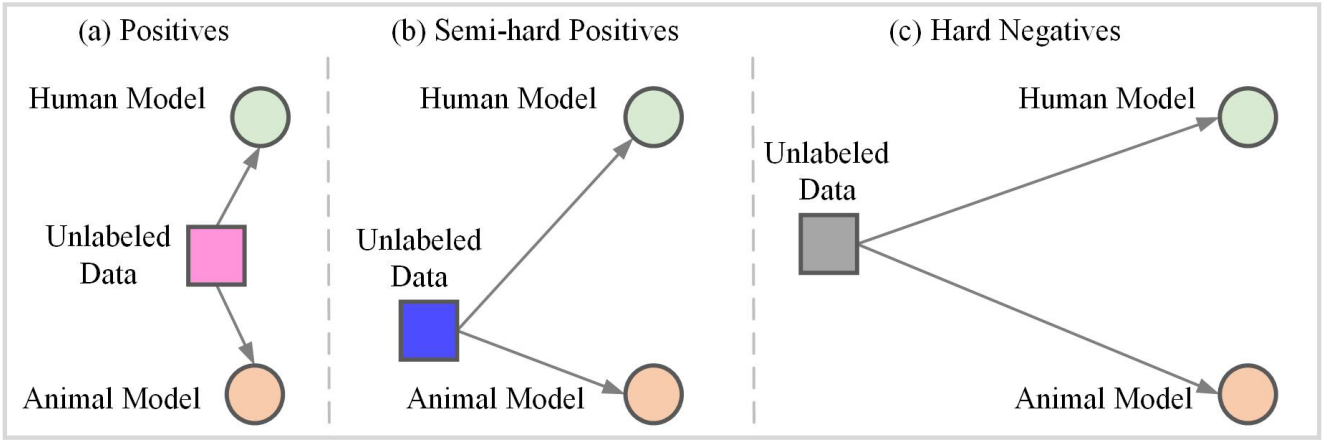
Gradients of the "new" network on few-shot data

$$f = \eta_{\mathcal{A}} \cdot \left(\nabla_{\theta_{\mathcal{A}}^{(t+1)}} \mathrm{MSE}(H_{fs}, \mathcal{A}(I_{fs}; \theta_{\mathcal{A}}^{(t+1)}))\right)^{\mathrm{T}} \cdot \nabla_{\theta_{\mathcal{A}}} \mathrm{MSE}(\hat{H}_u, \mathcal{A}(I_u; \theta_{\mathcal{A}}^{(t)}))$$

Gradients of the "old" network on large-scale unlabeled data

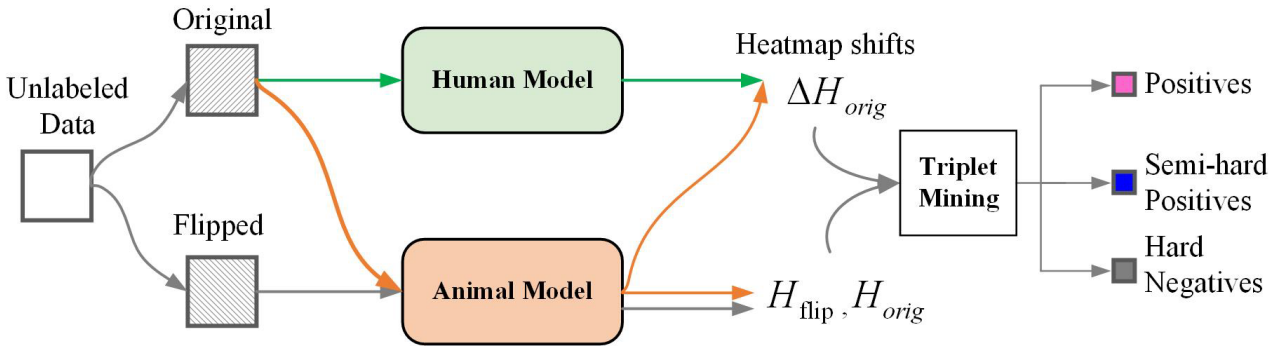
Positive example mining



If the **ground truth** is known, it is easy to identify **three** types of unlabeled data

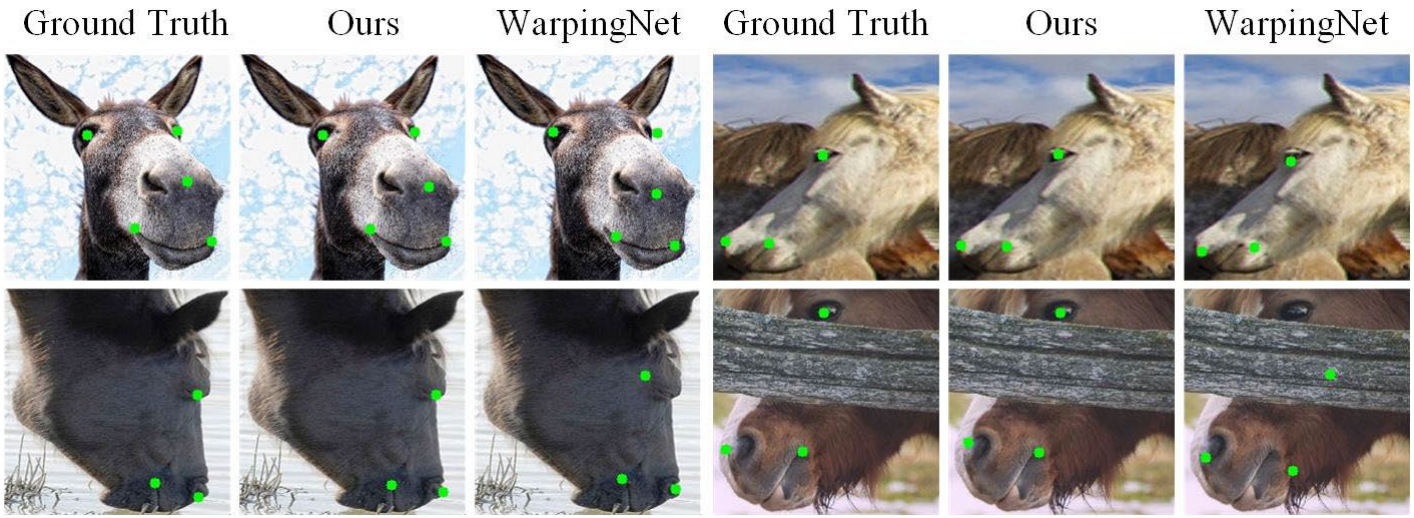
Positive example mining

No ground truth is available!



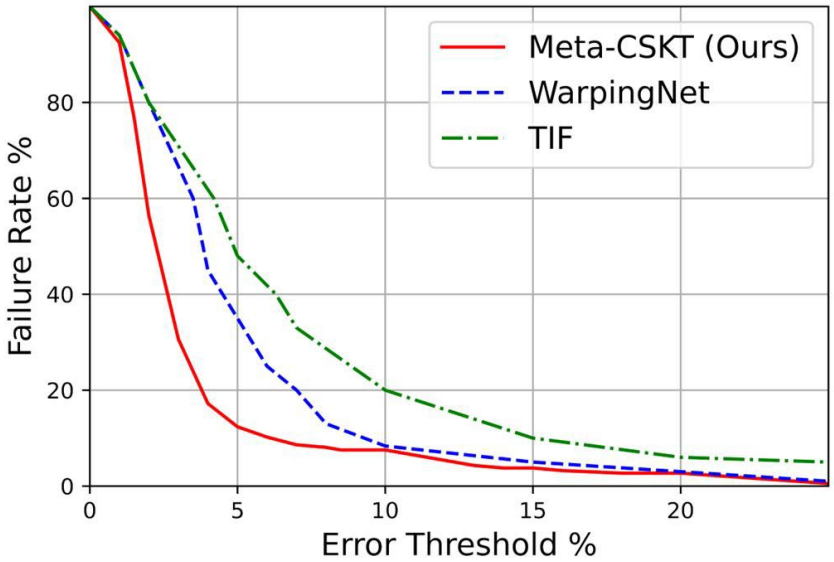
- If $\left\| H_{flip} - Flip(H_{orig}) \right\|^2 > \mathrm{T}_{neg}$, the unlabeled data is hard negative
- If $\Delta H_{orig} < T_{pos}$, the unlabeled data is positive
- Elsewise, the unlabeled data is semi-hard positives

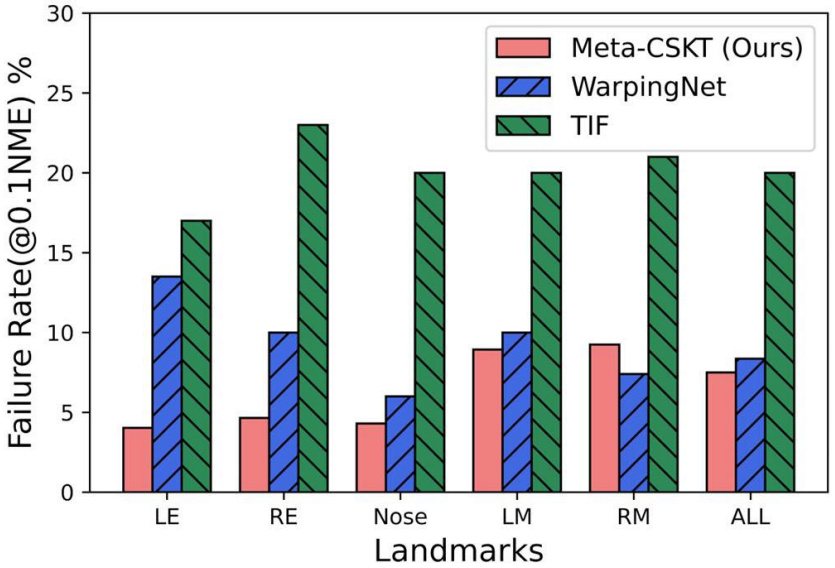
Evaluation on Horse Facial Keypoint dataset



Robust to occlusion and large pose variations

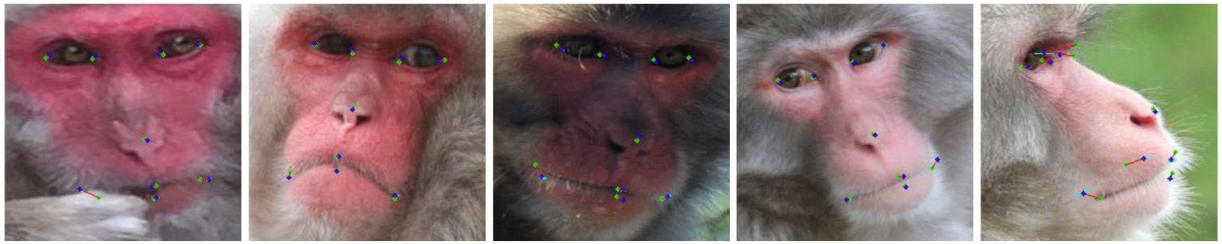
Evaluation on Horse Facial Keypoint dataset



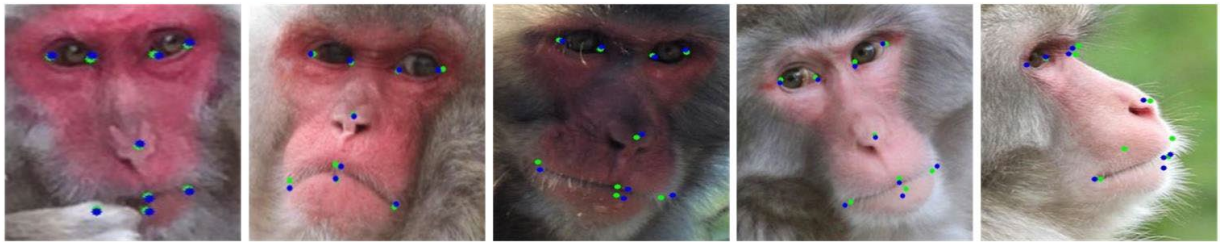


Evaluation on Japanese Macaque Species

MDMD



Ours



Models	MDMD Base	MDMD 300W	ViTPose+B	Ours
NME	3.66	3.44	4.69	**2.96**

Evaluation on AnimalWeb

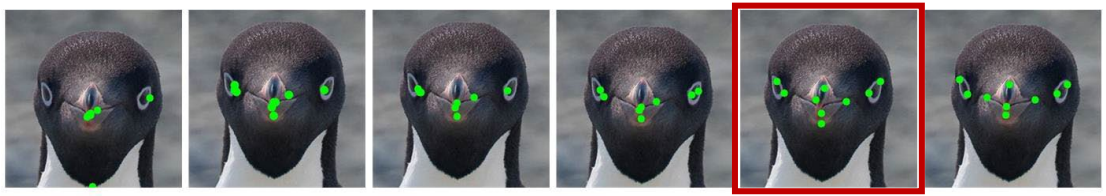
Models (Known)	# Labeled Image	NME	Models (Unknown)	# Labeled Image	NME
HG2	17.96K	5.22	HG2	17.62K	6.14
HG3	17.96K	5.12	HG3	17.62K	5.96
Ours	40	5.61	Ours	40	7.44
	80	5.55		80	7.21

Our method achieves comparable performance while utilizing significantly fewer labeled data

- Known species setting: comparable
- Unknown species setting: acceptable gap (1%)
- Images: 40 or 80 versus 17+K; Images per species: 0.11 or 0.22 versus ~50

Effect of Meta-CSKT design

Models	Meta-cskt Loss			Positive Example Mining		NME Known/Unknown
	L_s	L_u	L_f	Exc. negative	Inc. positive	
1	✓	✘	✘	✘	✘	6.67/10.07
2	✓	✓	✘	✘	✘	6.03/9.03
3	✓	✓	✓	✘	✘	5.93/8.88
4	✓	✓	✓	✓	✘	5.89/8.84
Ours	✓	✓	✓	✓	✓	**5.61/7.44**



Conclusion

- Knowledge sharing among animals motivates Meta-CSKT, the first to leverage bi-directional cross-species knowledge transfer for data-scarce animal face alignment
- We propose positive example mining to effectively utilize unlabeled data: augment labeled data and purify unlabeled data
- Extensive experiments on three datasets demonstrate the superiority of our method for animal face alignment by using only a few labeled images

Please refer to our paper and the project page for more details and analyses:
https://www.danzeng.org/about/ , https://github.com/danzeng1990/Meta-CSKT

Paper

Project page

Thanks for attention

Contact: zengd@sustech.edu.cn