



LESS DATA

Deep Learning for Computer Vision

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Few-Shot Learning



Few-Shots Learning

LFW: Labeled Face in the Wild



Omniglot



Kaggle's Humpback Whale identification

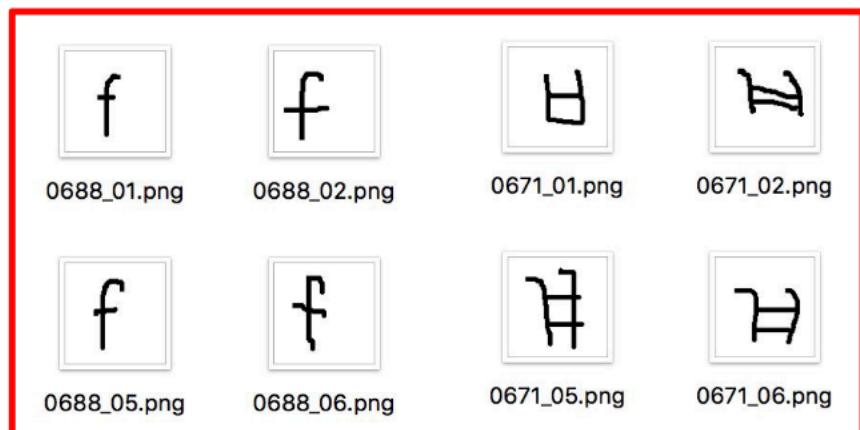


Few-Shots Learning



1. Learn to classify the few labeled samples in the **background set**
2. With a few labeled samples in **support set**, classify the **query set**

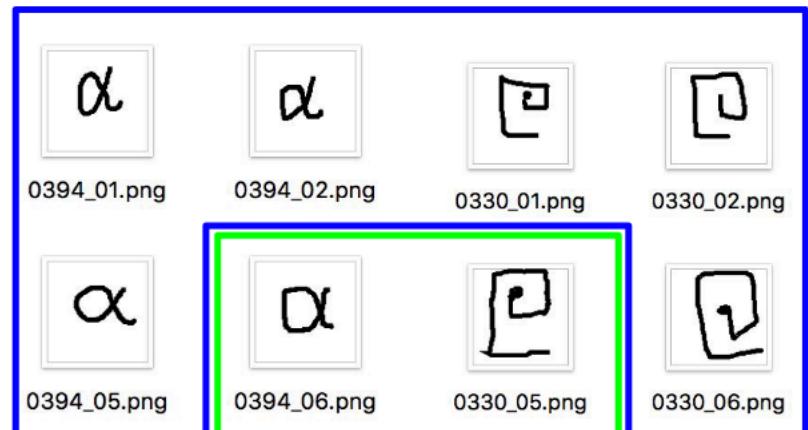
Training:



Latin F

Korean B/P

Testing:



Greek Alpha

Futurama F

Number of labeled samples / class: **K-shots**

Number of classes in testing: **N-ways**



A huge, potentially growing number of classes.

Less than a dozen labeled samples per class.

Discriminative model is impossible.

What if we learn a metric instead?



Distance:

$$d(x_1, x_2) = \|f(x_1) - f(x_2)\|_2 \in \mathbb{R}^+$$

Similarity:

$$s(x_1, x_2) = \cos(f(x_1), f(x_2)) \in [-1, +1]$$

With $f(x) \in \mathbb{R}^d$ a features extractor (e.g. ConvNet).

Given two images of the class, we want:

- Minimize distance
- Maximize similarity

Given two images of different classes, we want:

- Maximize distance
- Minimize similarity

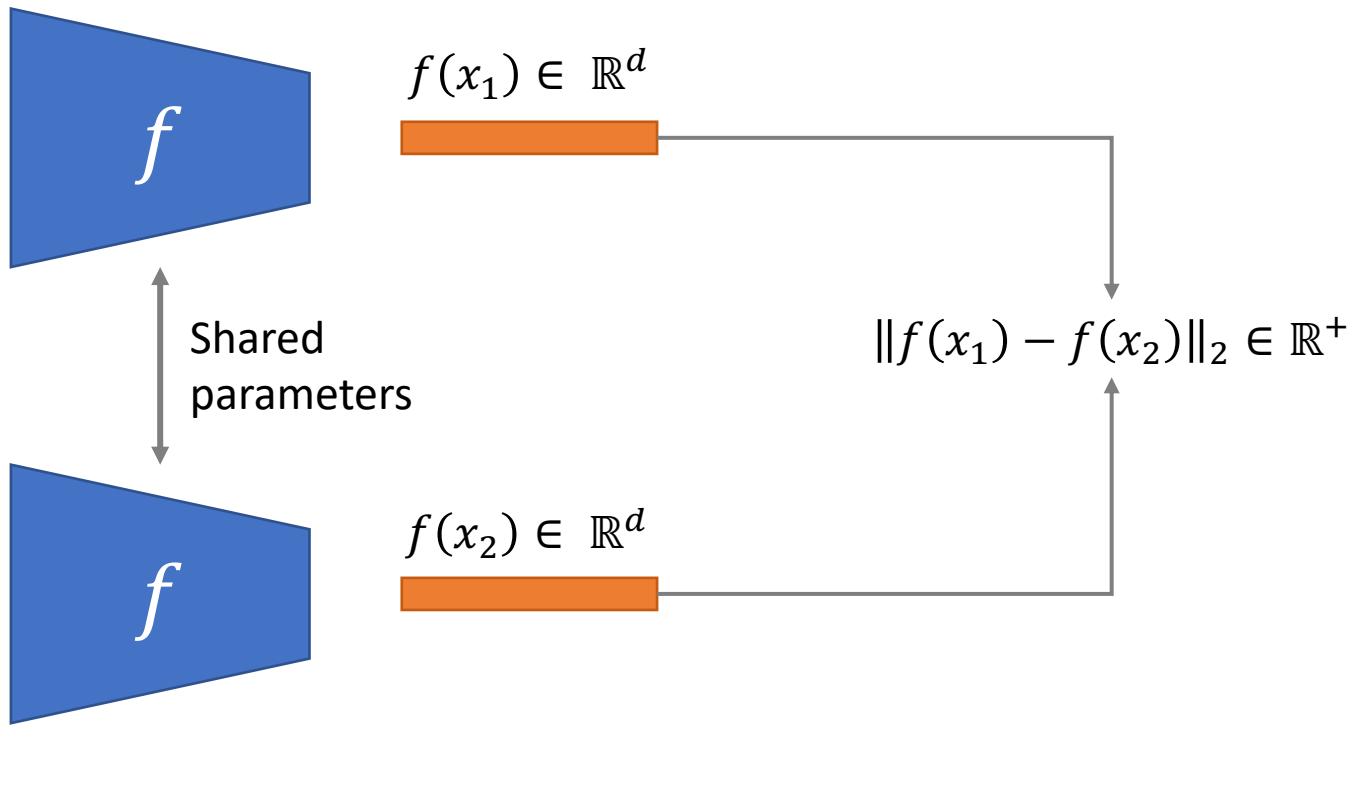
Siamese Network



x_1



x_2

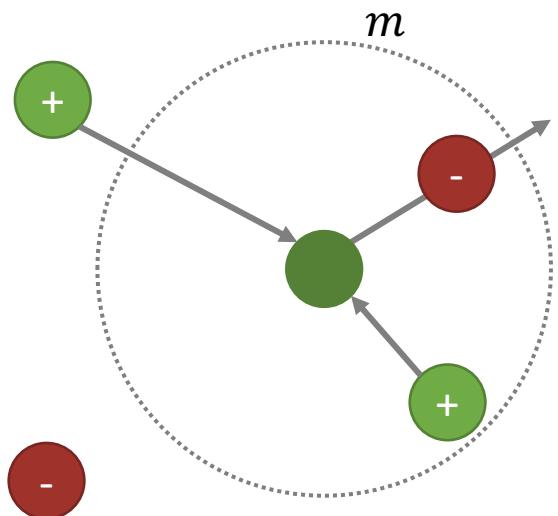


Contrastive Loss



$$D = \|f(x_1) - f(x_2)\|_2 \in \mathbb{R}^+$$

$$\mathcal{L}_{contrastive}(y, D) = \frac{1}{2}(1 - y)D^2 + \frac{1}{2}y \max(m - D, 0)^2$$



Weaknesses of Pairwise Models



- The margin m may be hard to tune, especially because distributions can change through training
- A double-margin may improve to avoid collapsing all positive samples together
- Try to learn an absolute distance between images

Triplet Network



We want to learn **relative distance** between samples

Given an anchor x_a , we want to have a small distance with a positive (same class) x_+ :

$$\min \|f(x_a) - f(x_+)\|_2$$

And maximize with a negative (different class) x_- :

$$\max \|f(x_a) - f(x_-)\|_2$$

Therefore we want that:

$$\begin{aligned} \|f(x_a) - f(x_-)\|_2 &> \|f(x_a) - f(x_+)\|_2 \\ \|f(x_a) - f(x_-)\|_2 - \|f(x_a) - f(x_+)\|_2 &> 0 \end{aligned}$$

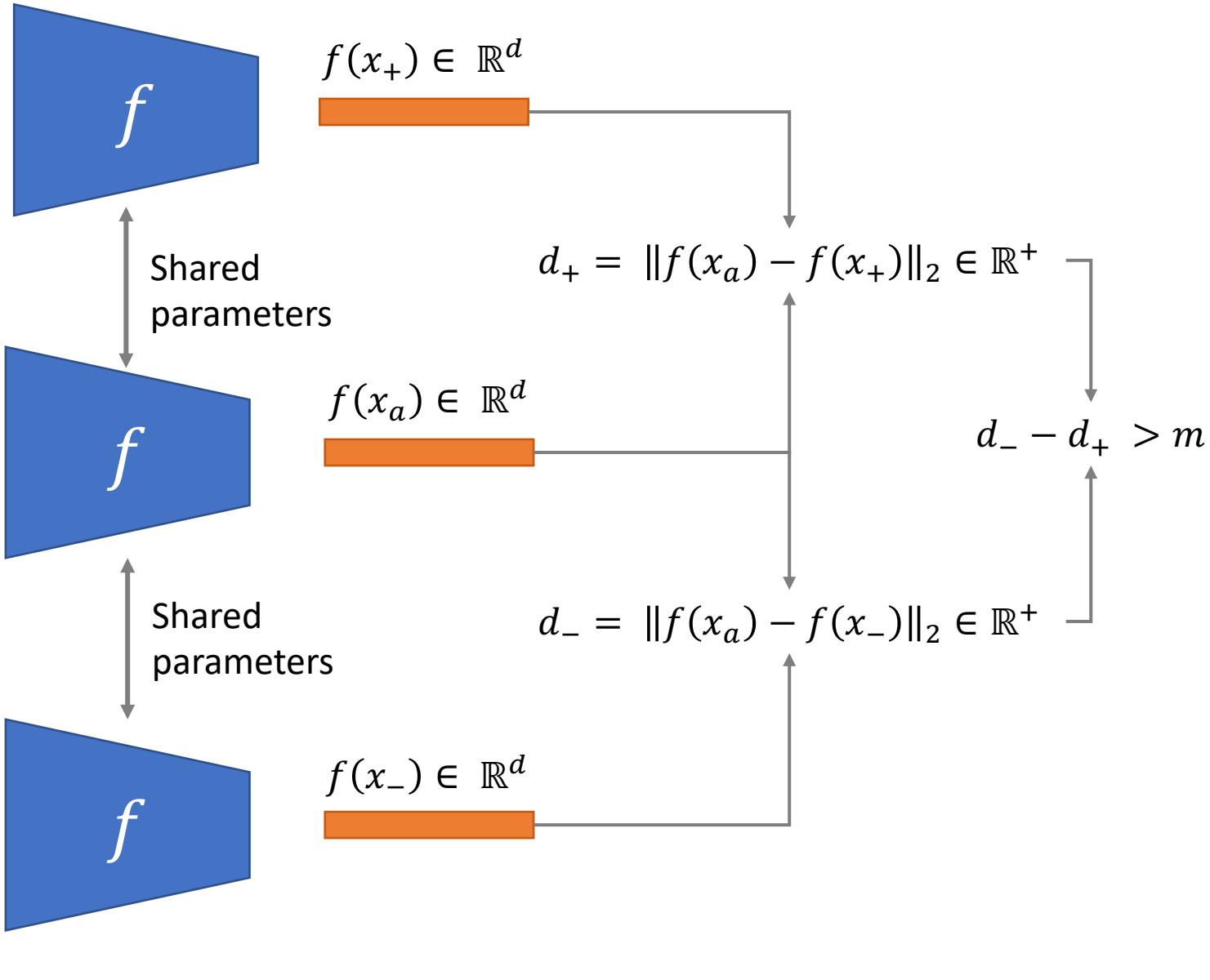
Add a margin m to ensure extra separability:

$$\|f(x_a) - f(x_-)\|_2 - \|f(x_a) - f(x_+)\|_2 > m$$

Thus the loss is:

$$\min \max(\|f(x_a) - f(x_+)\|_2 - \|f(x_a) - f(x_-)\|_2 + m, 0)$$

Triplet Network

 x_+  x_a  x_- 

Hard Negative Mining



Most triplets are easy.

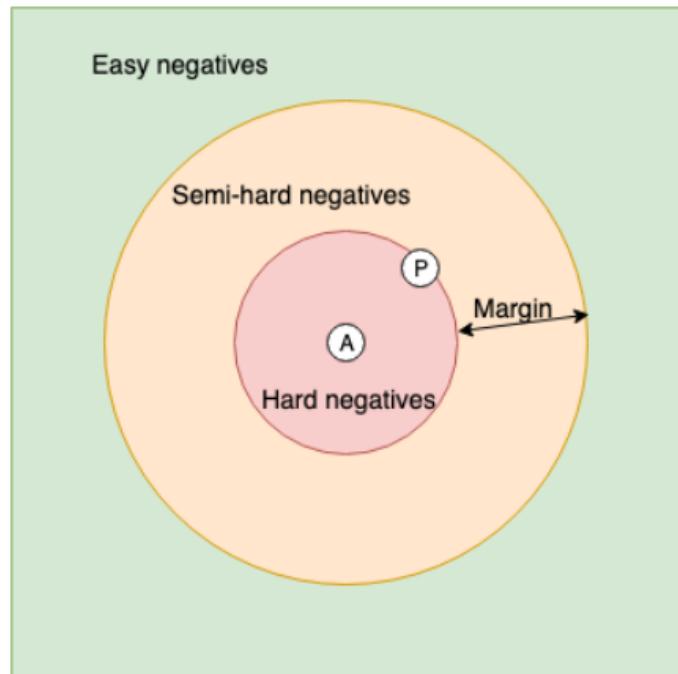
We want to sample either:

Hard negatives:

$$\|f(x_a) - f(x_+)\|_2 > \|f(x_a) - f(x_-)\| + m$$

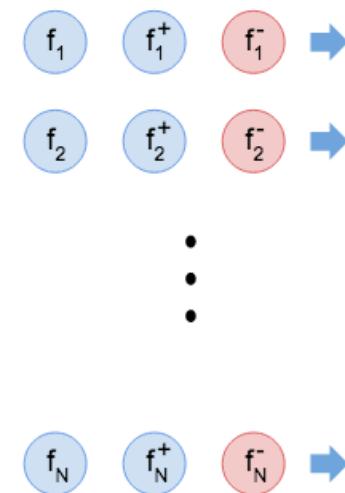
Semi-Hard negatives:

$$\|f(x_a) - f(x_+)\|_2 > \|f(x_a) - f(x_-)\|$$

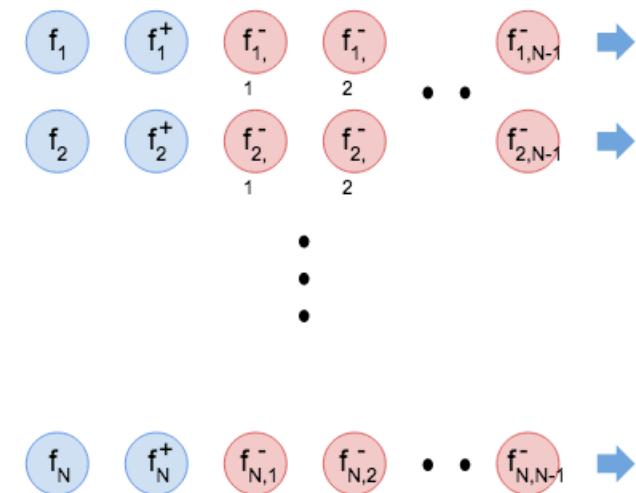


Pretty much essential to have State-of-the-Art performance with Triplet Networks!

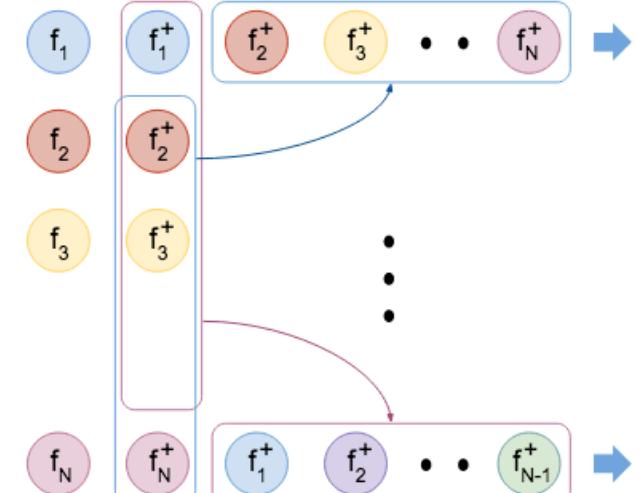
N-Pairs



(a) Triplet loss



(b) $(N+1)$ -tuple loss

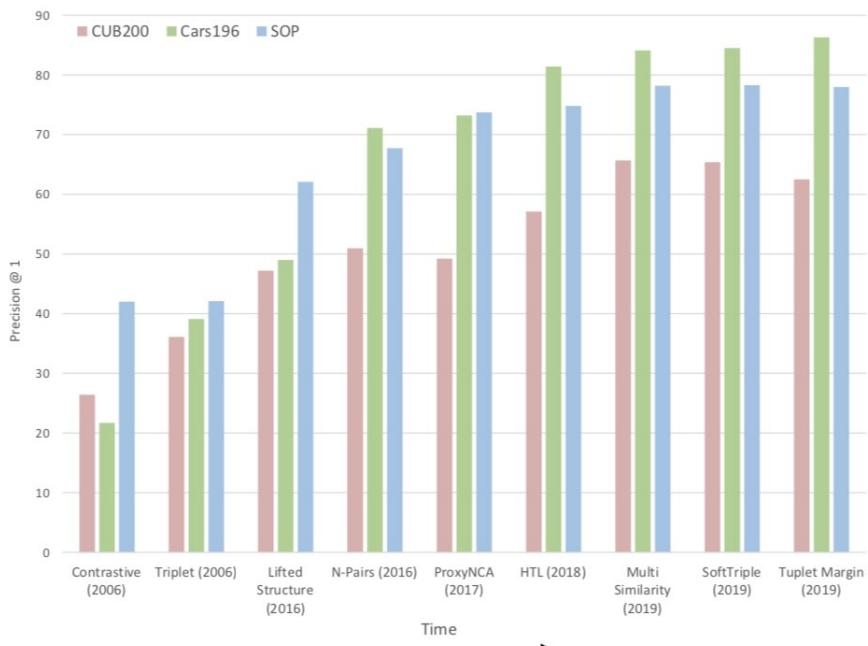


(c) N -pair-mc loss

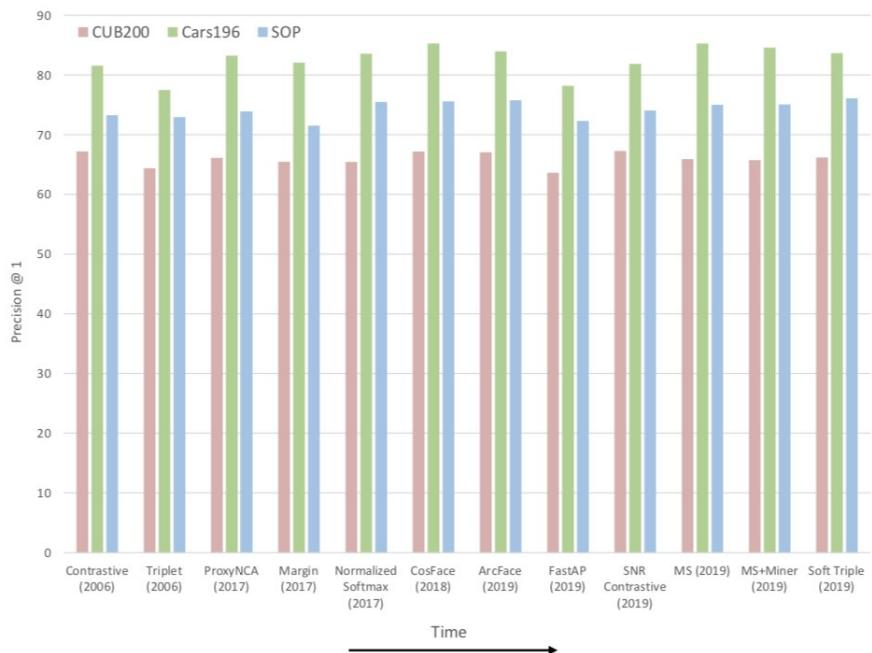
Efficient generalization of Triplet networks that uses the whole batch.



Troubles in Metric Learning...



(a) The trend according to papers



(b) The trend according to reality

Fig. 4. Papers versus Reality: the trend of Precision@1 of various methods over the years.

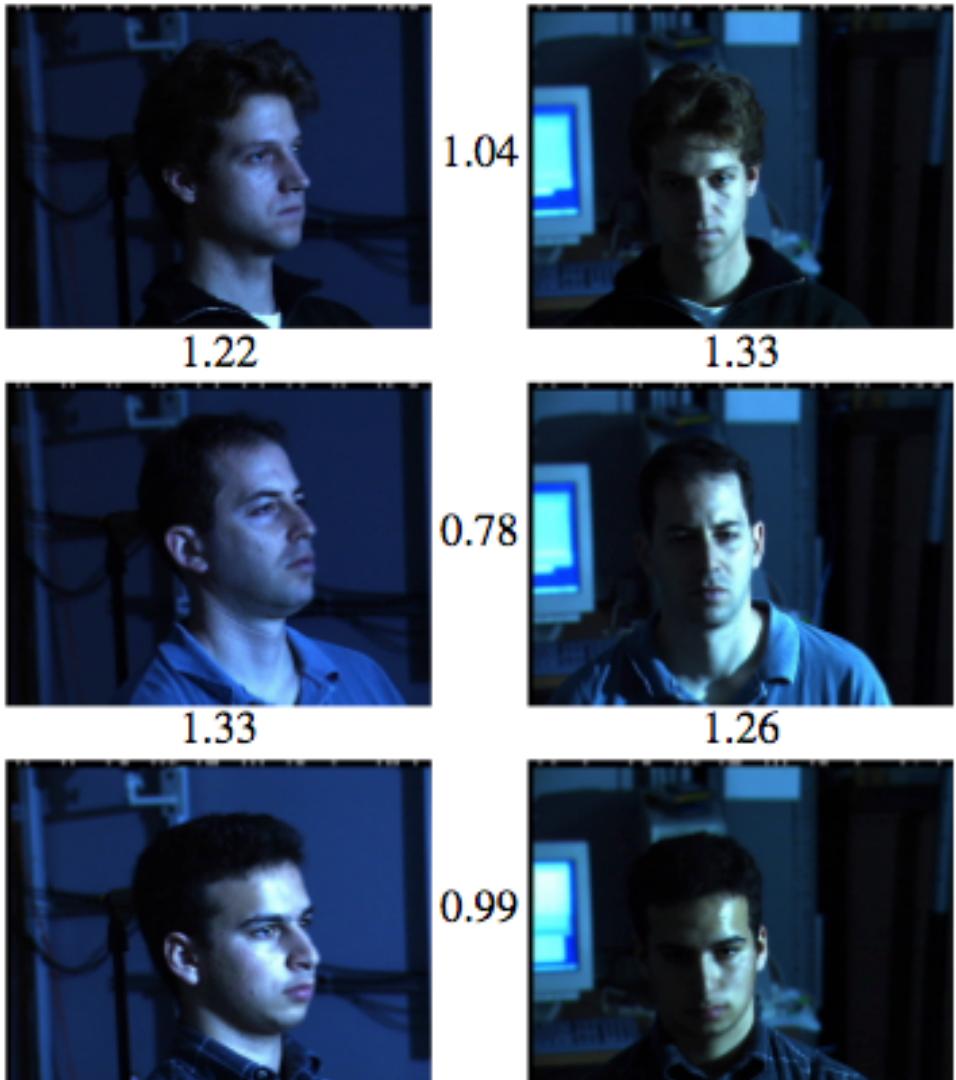
The gain of more recent Metric Learning models may come from:

- Better backbone
- Better hyperparameters tuning
- Better data augmentation



Triplet Network with semi-hard negative mining.

Pretty much solved the LFW dataset.



Distance between pairs

Meta-Learning MAML



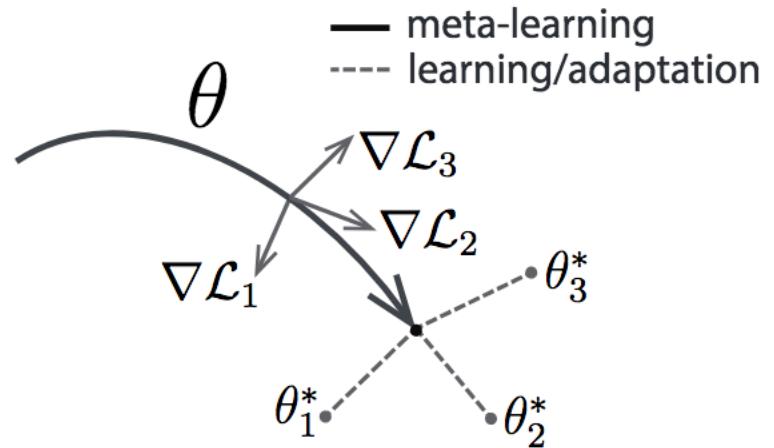
Learning to learn:

→ Given a few samples can learn faster

Outer and inner loop:

- Inner loop learns to classify well a few labeled samples.
- Outer loop learns to have good weights for the inner loop.

During inference, perform only inner loop.



Algorithm 1 Model-Agnostic Meta-Learning

Require: $p(\mathcal{T})$: distribution over tasks
Require: α, β : step size hyperparameters

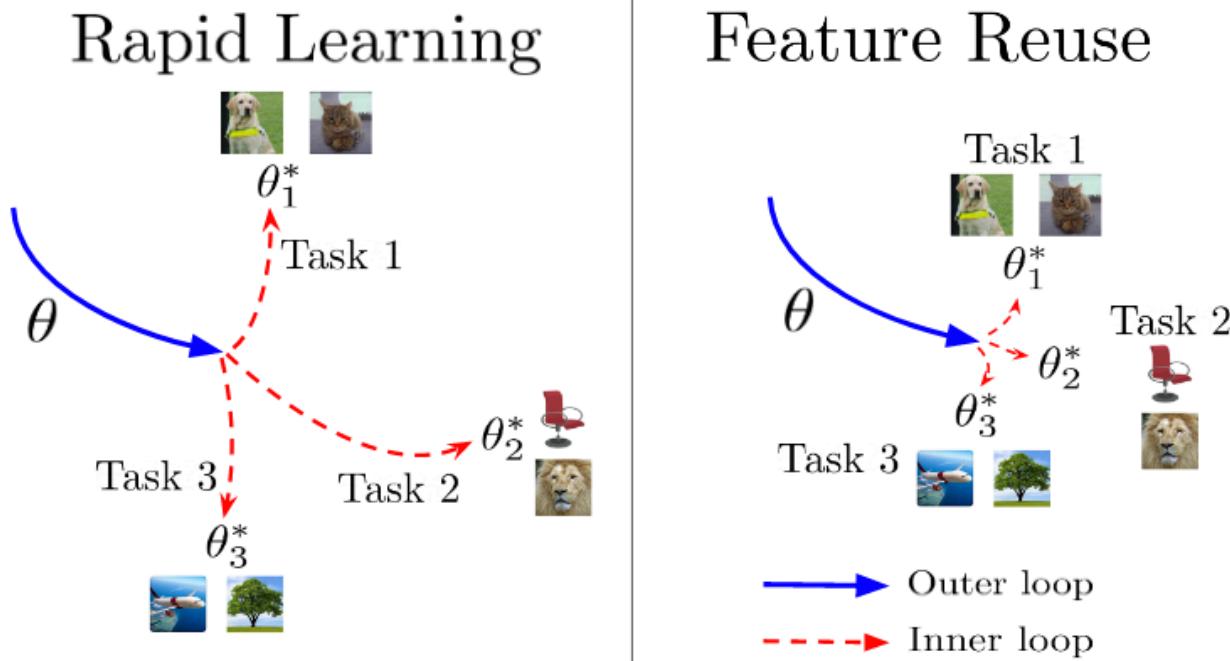
- 1: randomly initialize θ
- 2: **while** not done **do**
- 3: Sample batch of tasks $\mathcal{T}_i \sim p(\mathcal{T})$
- 4: **for all** \mathcal{T}_i **do**
- 5: Evaluate $\nabla_{\theta} \mathcal{L}_{\mathcal{T}_i}(f_{\theta})$ with respect to K examples
- 6: Compute adapted parameters with gradient descent: $\theta'_i = \theta - \alpha \nabla_{\theta} \mathcal{L}_{\mathcal{T}_i}(f_{\theta})$
- 7: **end for**
- 8: Update $\theta \leftarrow \theta - \beta \nabla_{\theta} \sum_{\mathcal{T}_i \sim p(\mathcal{T})} \mathcal{L}_{\mathcal{T}_i}(f_{\theta'_i})$
- 9: **end while**

Meta-Learning MAML



Does MAML *really* learns to learn (**rapid learning**)?

More probably it manages to learn features that generalize well (**feature reuse**)



Self-Supervised Learning

(also Unsupervised Learning)

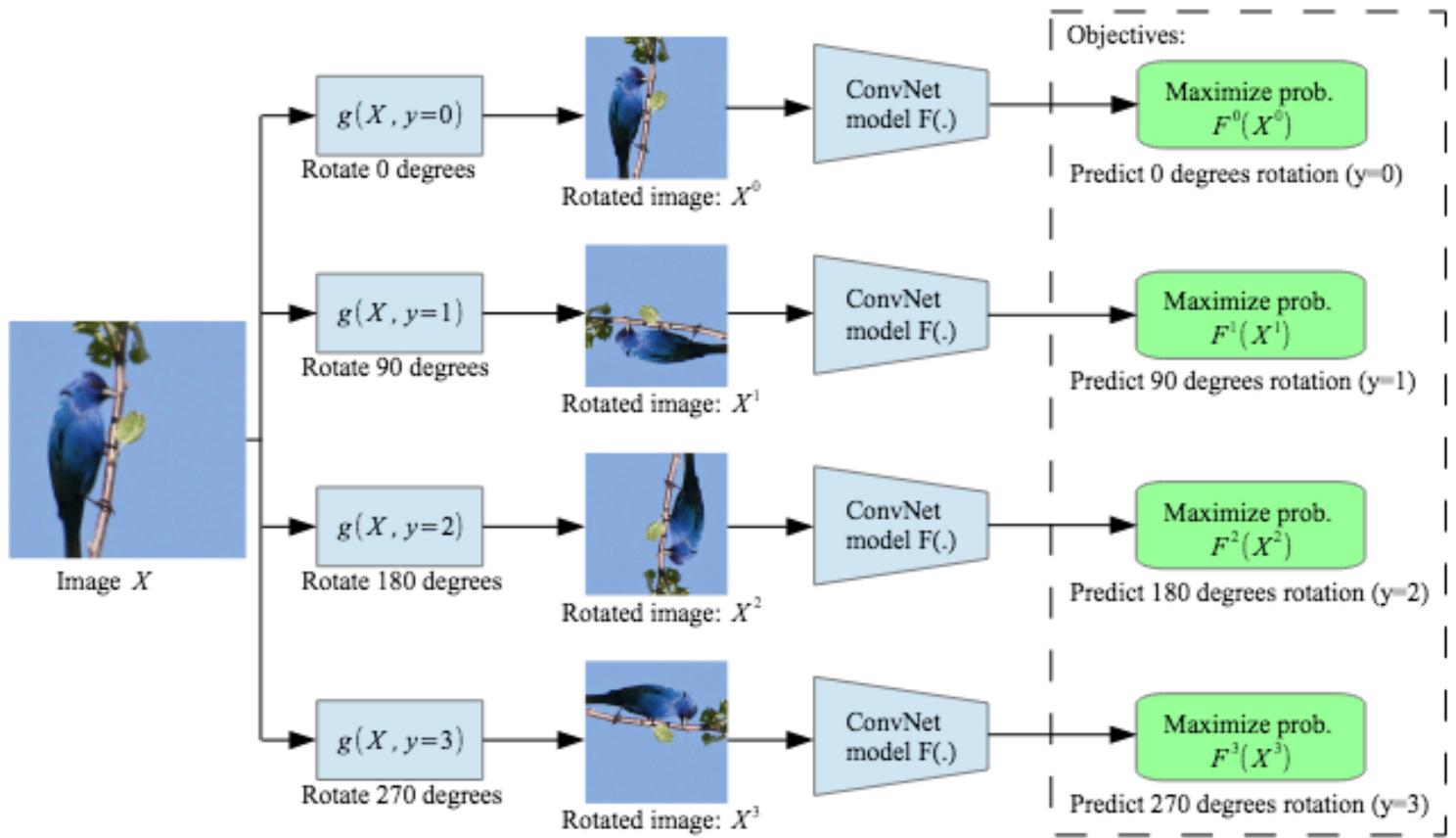


Setting

1. Learn a backbone with a lot of **unlabeled data** using a self-designed objective
 2. Freeze the backbone
 3. Learn a classifier on top of it on labeled data.
- Evaluate how much the learned representation (features extracted by ConvNet) is useful.

It can be useful to have a good model pretraining in order to do transfer learning later.

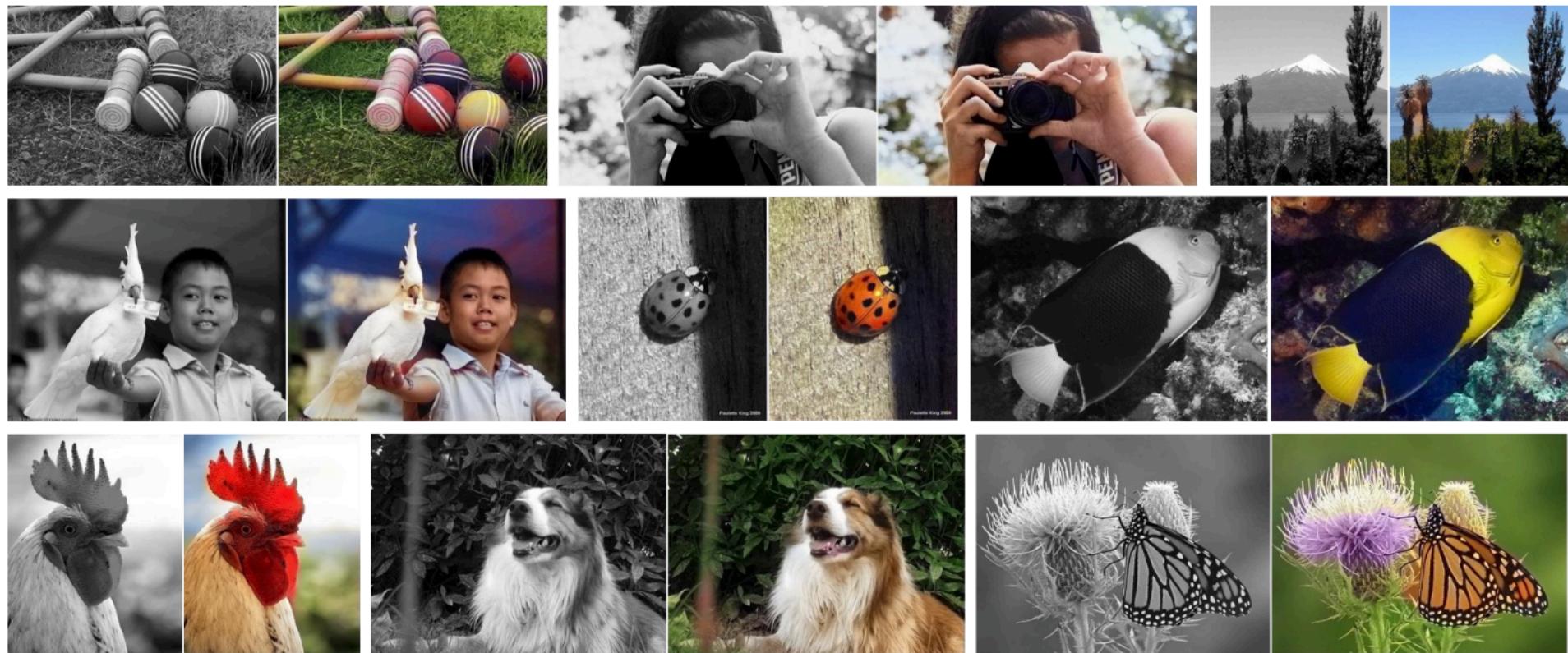
Rotation



Learn what is the rotation applied.

→ Thus it must learn what is the structure of the visual world.

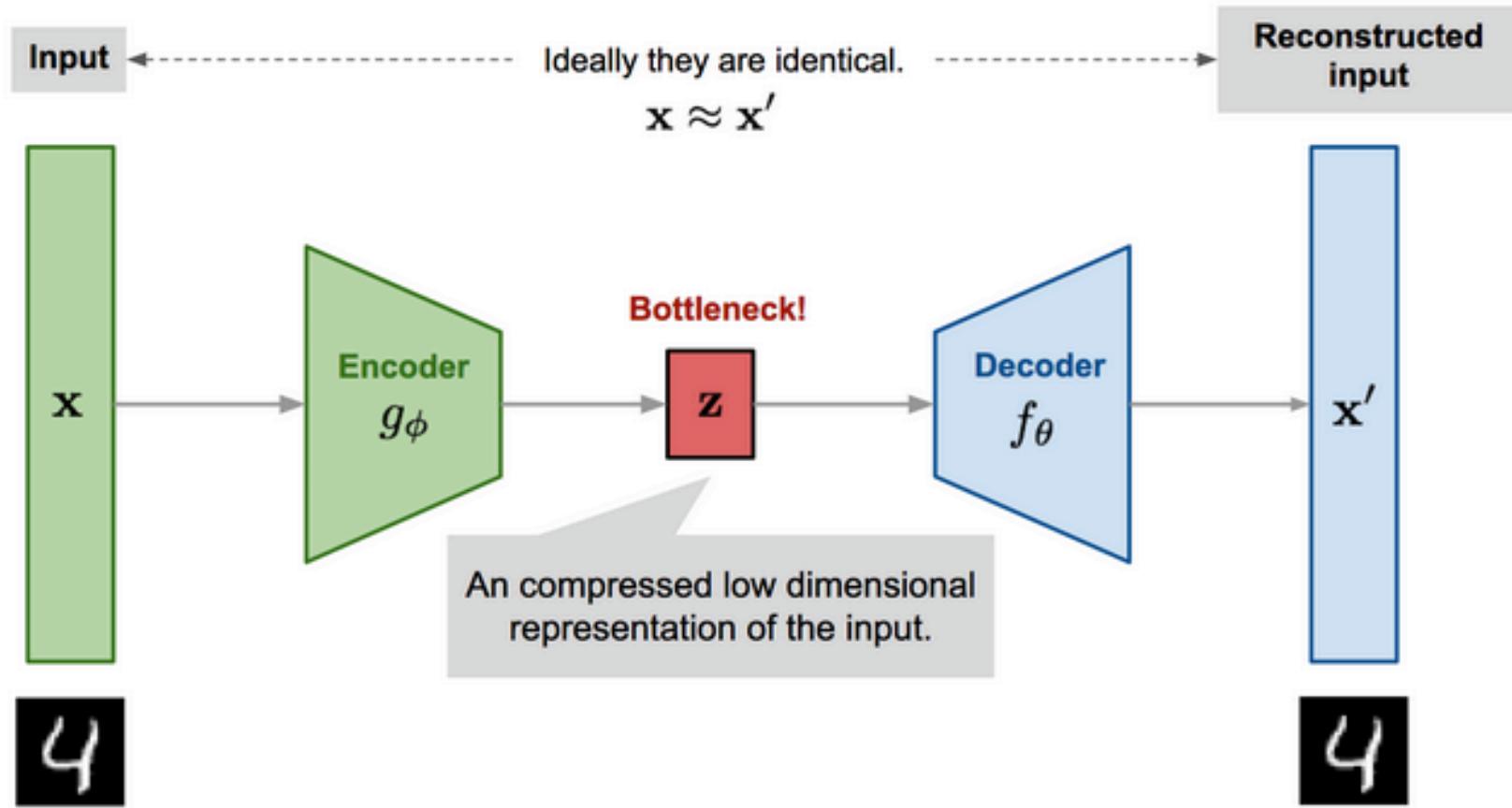
Colorization



Learns to predict the colors from “*grayscale*” images.

- Regression problem
- Done in the LAB space instead of RGB

Auto-Encoder



Compress an image and then reconstruct it.

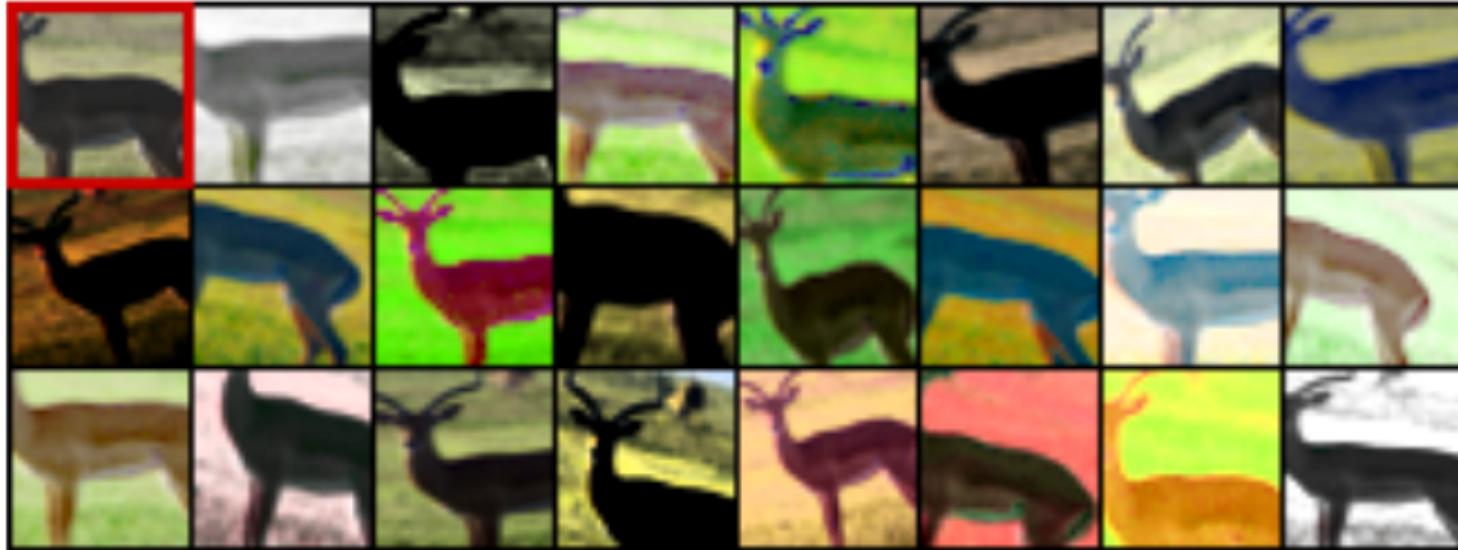
- Similarly to method of dimensionality reduction like PCA
- It must only keep important features.



Each image is considered as a class.

New samples of this “class” are generated with heavy data augmentation.

Trained with usual softmax + cross-entropy.

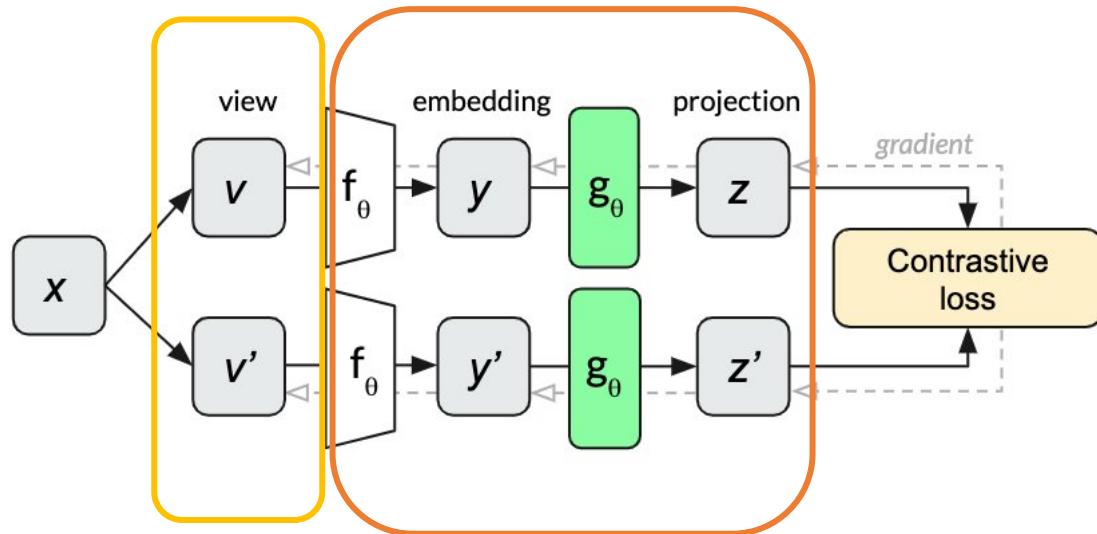


Most of future self-supervised models also try to:

- Bring together the same image augmented differently
- Push away all others images



Batch of images is augmented twice differently



Extract features with ConvNet f_θ ,
then project it with a small MLP
to produce $z \in \mathbb{R}^d$

Alternative version of the contrastive loss.

→ Bring together the same image augmented differently

→ Push away all others images of the batch

$$-\log \frac{\exp(s_{i,j}/\tau)}{\sum_{k=1}^{2N} \mathbb{1}_{[k \neq i]} \exp(s_{i,k}/\tau)}$$



Alternative version of the contrastive loss.

- Bring together the same image augmented differently
- Push away all others images of the batch

$$-\log \frac{\exp(s_{i,j}/\tau)}{\sum_{k=1}^{2N} \mathbb{1}_{[k \neq i]} \exp(s_{i,k}/\tau)}$$

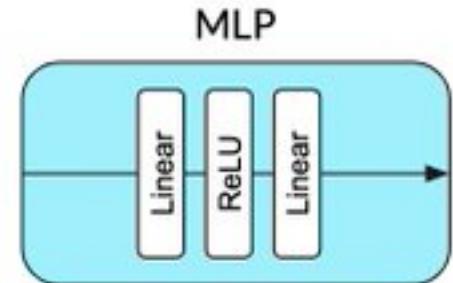
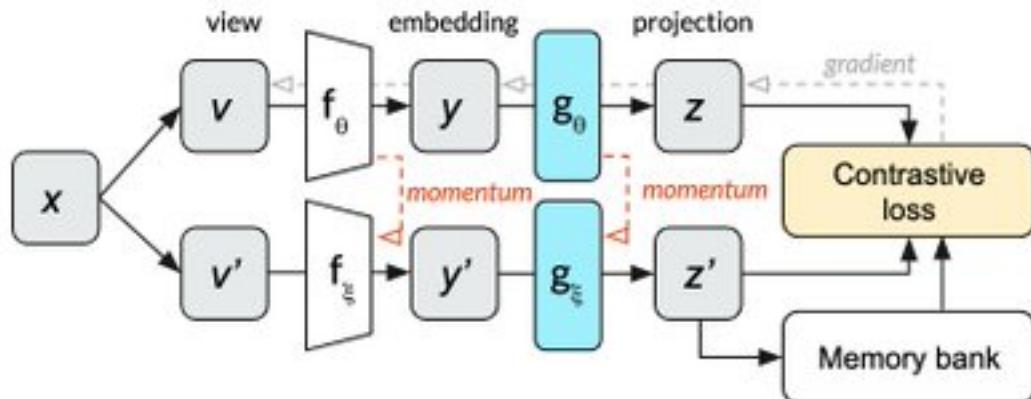
It needs a very large batch size ≥ 1024 !

The MLP that does the projection is essential.

- Learns useful transformations for the contrastive task
- But it discarded during the finetuning phase



MoCov2

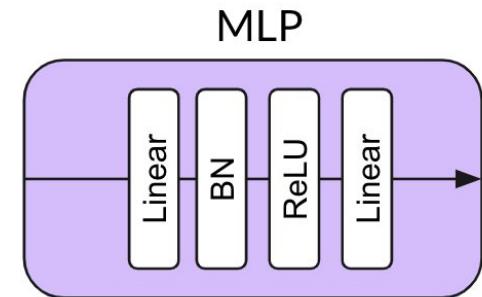
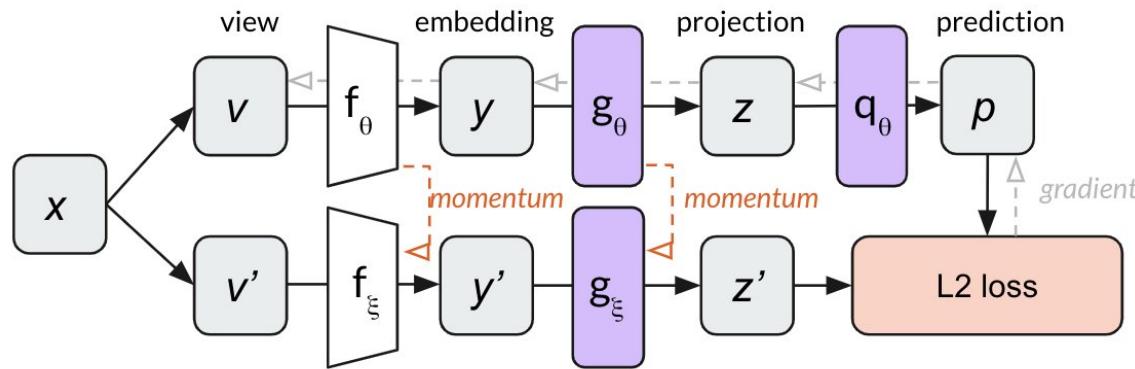


Reduces the need of large batch size with a **memory bank**:

- Stores previously computed projections z'
- Means more negative in the contrastive loss

The gradient is backpropagated only through one version of the network:

- The other network is, as in RL, a **target network**
- It is updated with momentum $\theta_t \leftarrow \alpha \theta_t + (1 - \alpha) \theta_s$
- Enforce stability in the memory bank representations



L2 distance between **only positive examples, not negative examples are used!**

Why does the representation do not collapse?

→ Meaning only producing a zero vector for any input would minimize the loss

Still an active area of research, but some intuitions:

→ Asymmetrical architecture with another MLP q_θ

→ Momentum for the target network

What do we actually need for self-supervision?



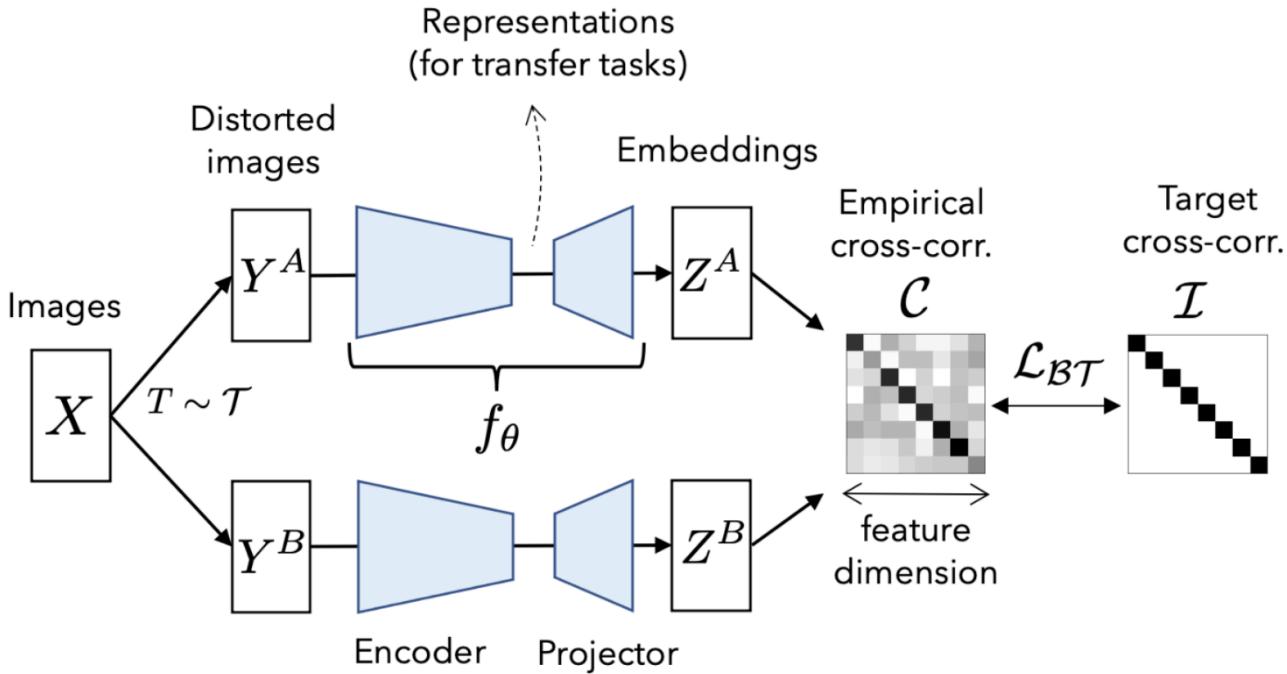
Invariance to transformations:

- Two augmentations of the same image should produce the same representation

Disentangling of the dimensions:

- Each dimension of the representation should encode a different info

Barlow Twins



Cross-correlation along the batch dimension:

$$\mathcal{C}_{ij} \triangleq \frac{\sum_b z_{b,i}^A z_{b,j}^B}{\sqrt{\sum_b (z_{b,i}^A)^2} \sqrt{\sum_b (z_{b,j}^B)^2}}$$

$$\mathcal{L}_{\mathcal{BT}} \triangleq \underbrace{\sum_i (1 - \mathcal{C}_{ii})^2}_{\text{invariance term}} + \lambda \underbrace{\sum_i \sum_{j \neq i} \mathcal{C}_{ij}^2}_{\text{redundancy reduction term}}$$

Invariance to transformations:

- First term forces each dimension i from both views to be very correlated (+1) despite the views were generated by different transformations

Disentangling of the dimensions:

- Second term forces each dimension i to be orthogonal (0) with dimension $j \neq i$ so that each dimension encodes a different information, aka no collapse

Domain Adaptation



Setting

- Source domain/dataset is fully labeled
- Target domain/dataset is unlabeled
- Both represent the same classes
- Huge discrepancy in the pixels distribution

	MNIST	SYN NUMBERS	SVHN	SYN SIGNS
SOURCE				
TARGET				
	MNIST-M	SVHN	MNIST	GTSRB

Source Domain



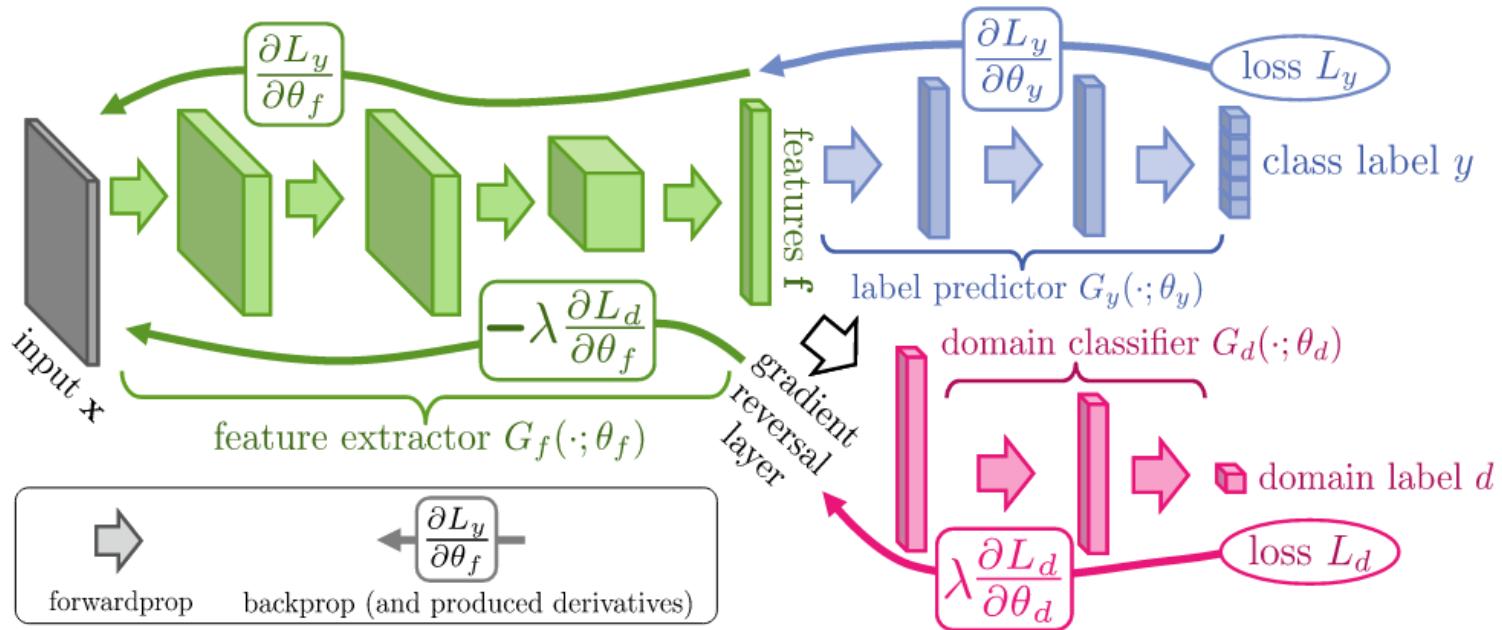
GTA5 (yes the game)

Target Domain



Cityscapes

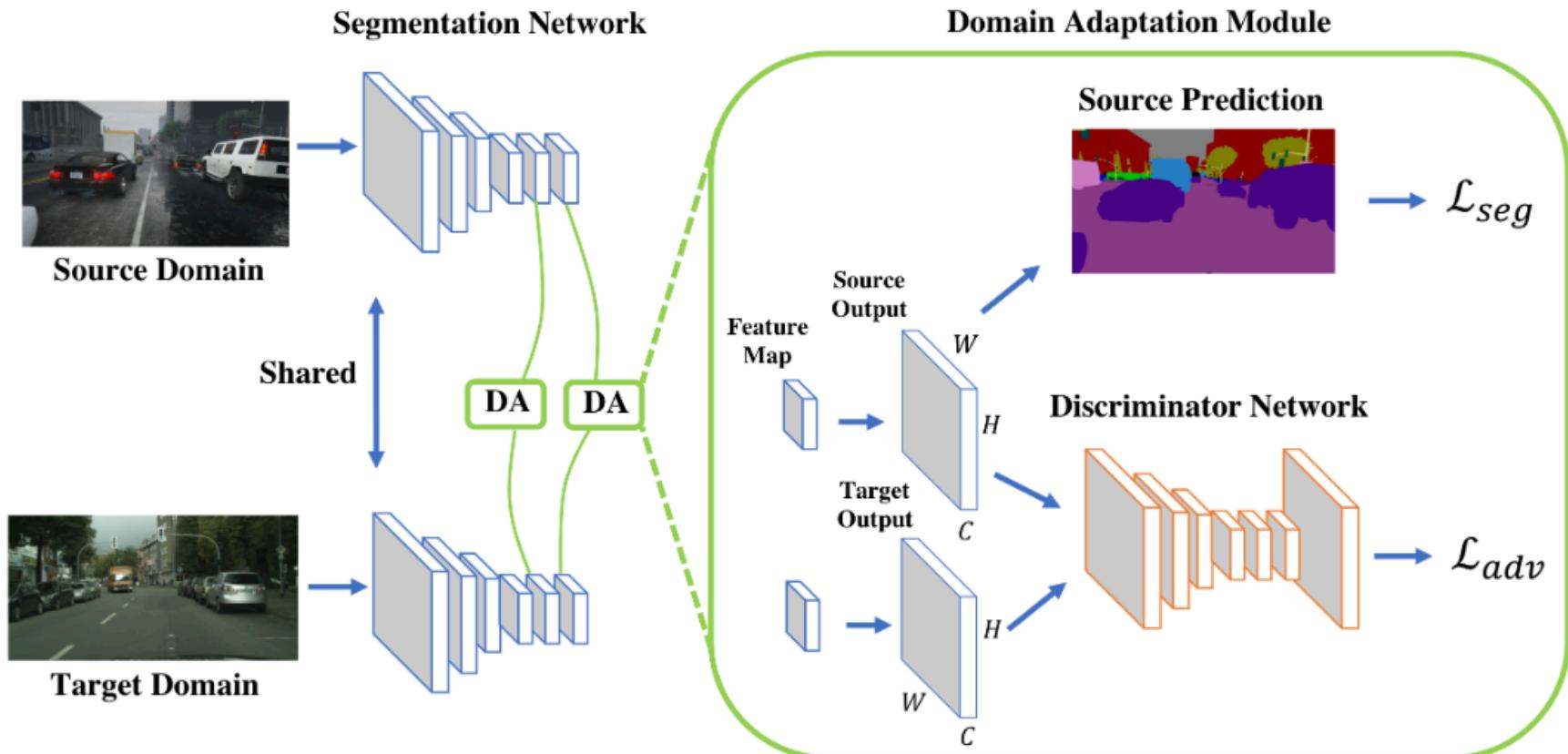
DANN: Gradient Reversal Layer



Gradient Reversal Layer (GRL) forces the ConvNet to maximize the loss of the Domain Classifier.

→ Force to learn domain agnostic features

AdaptSegNet



- Train the Discriminator on the probabilities of the source and target without the gradient flowing backward
- Train the Segmentation Network on source for classification and also force the discriminator to predict source given target images

$$\max_{\mathbf{D}} \min_{\mathbf{G}} \mathcal{L}(I_s, I_t). \quad \mathcal{L}(I_s, I_t) = \mathcal{L}_{seg}(I_s) + \lambda_{adv} \mathcal{L}_{adv}(I_t)$$



Two key ideas

Two key ideas for domain adaption in segmentation:

1. **Adversarial loss** forcing a similar representation for both source and target domains
2. **Pseudo-labeling** to generates labels for the unlabeled target domain

Other Problems

Not covered in this lecture



Zero-shot Learning:

- Not a single image of the class to predict, but access to metadata
- *Ex: understand a Wikipedia description to classify a never-seen before animal*

Semi-Supervised:

- A few amount (~10%) of the data is labeled, while the remaining is unlabeled but present
- Most of the recent self-supervision literature took a lot of inspiration from it
- Often solved with contrastive, weights averaging, and pseudo-labeling with consistency

Weak supervision:

- Labels are imperfect
- *Ex: training a model to predict the hashtag on Instagram photos*

Small break,
then coding session!