Rotate your networks: better weight consolidation and less catastrophic forgetting

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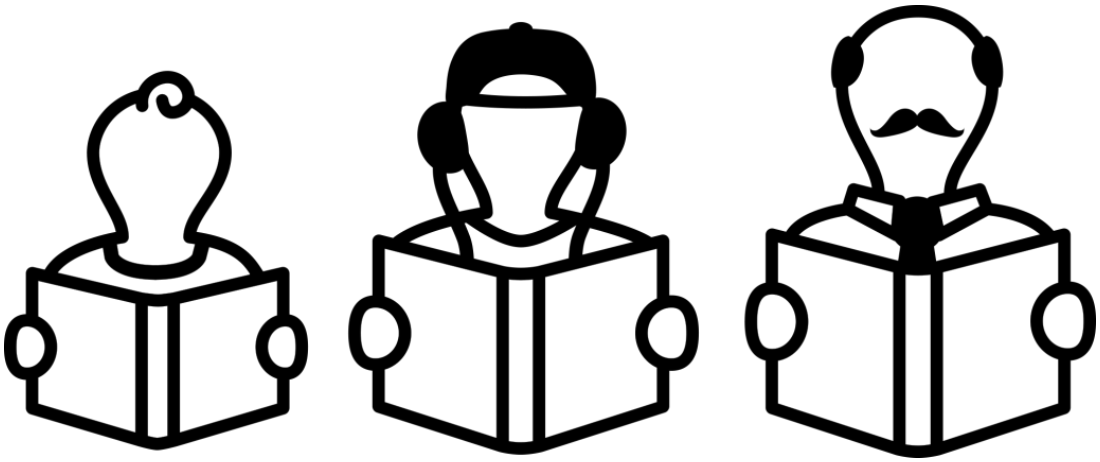
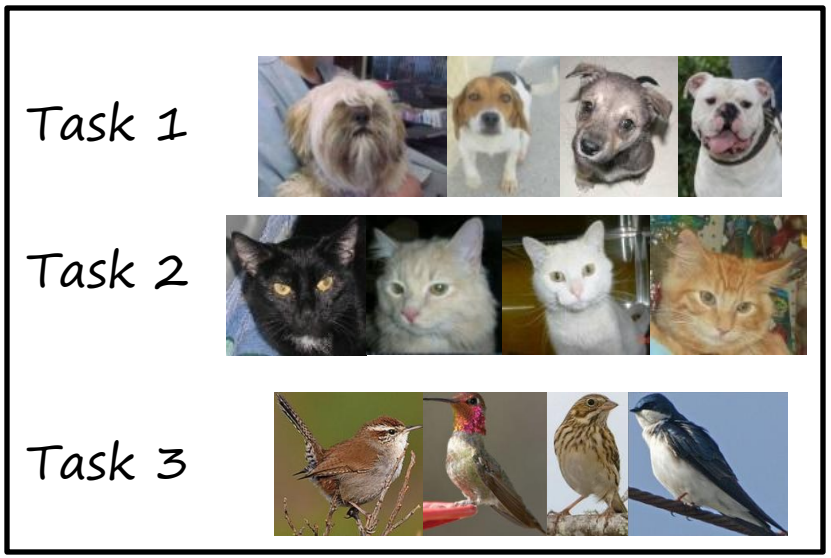
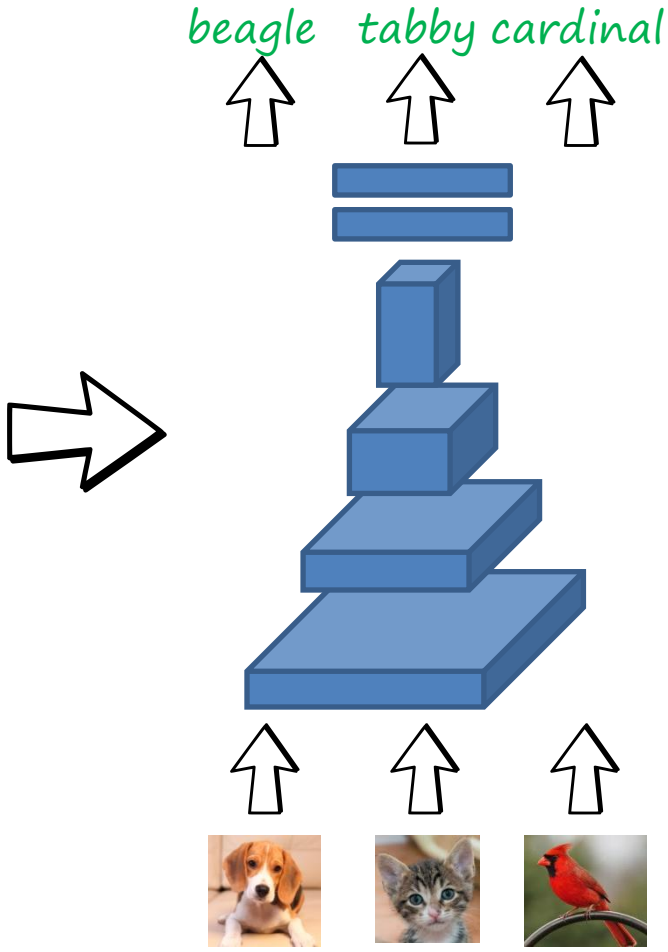
Lifelong learning

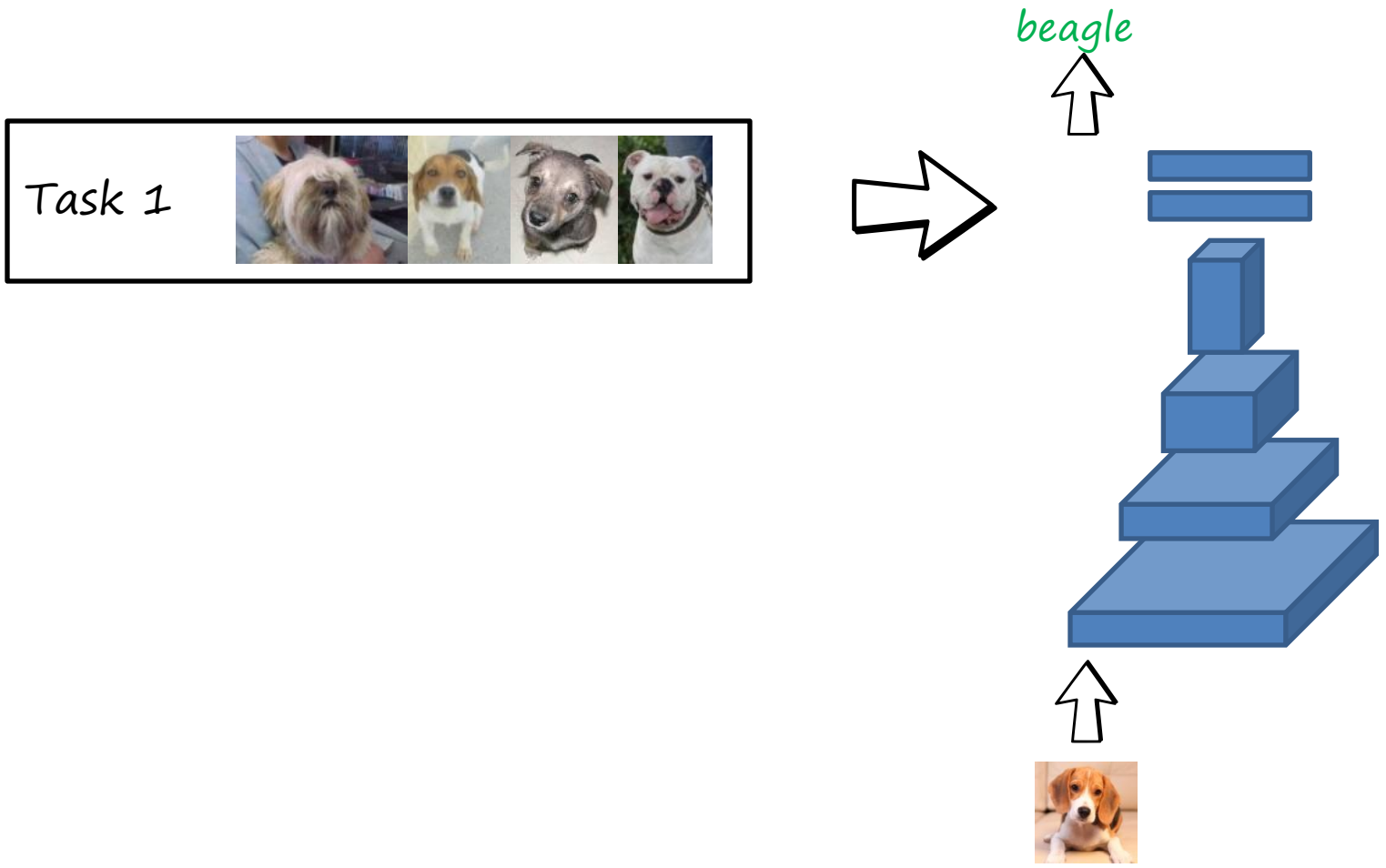


Joint learning

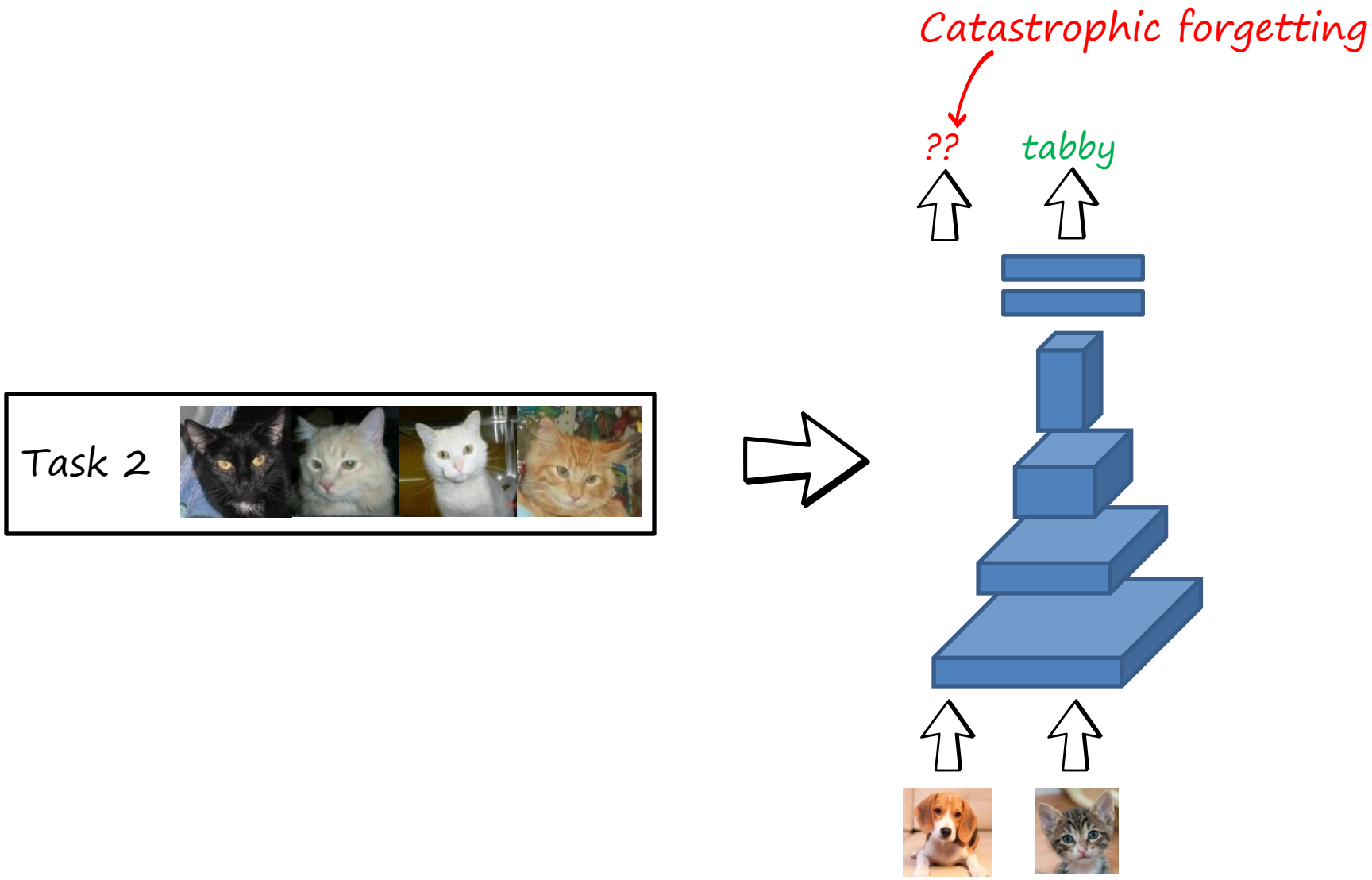




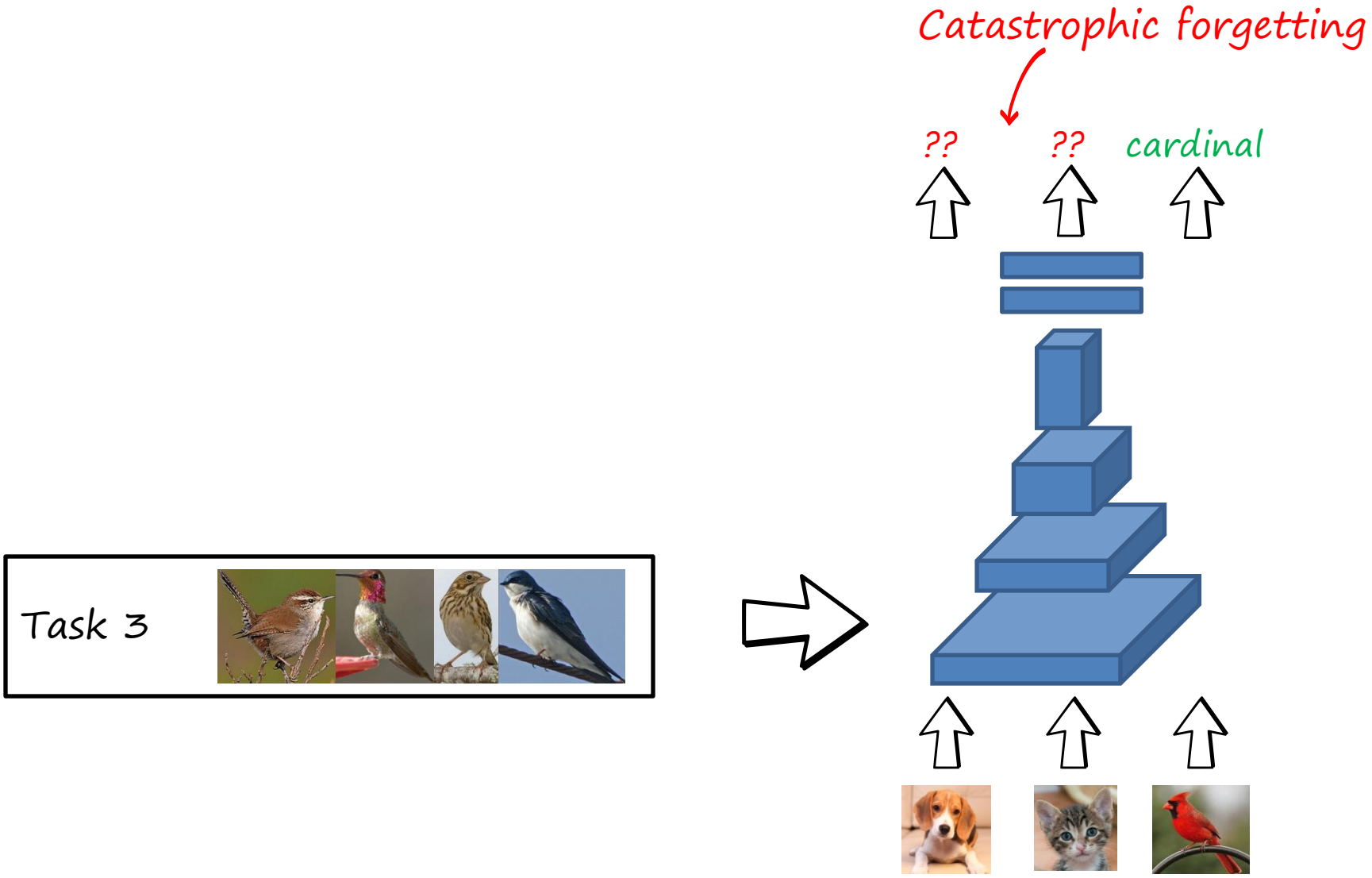
Sequential learning



Sequential learning



Sequential learning



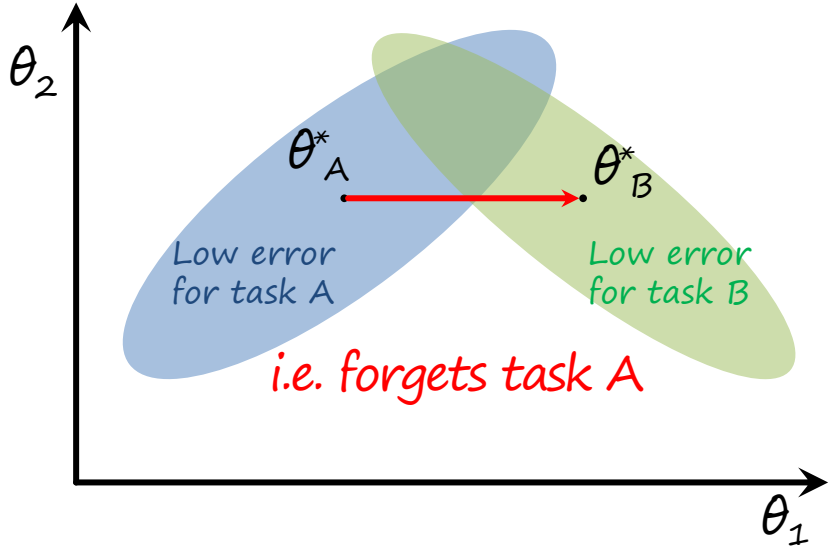
Preventing catastrophic forgetting

- Memories, replay and retrain
  - A few real samples (**exemplars**) from previous tasks
  - A generative **model** for previous data and sample
- Regularization
  - Weights
  - Activations
- Develop modularity
  - Enforce using different weights/neurons for different tasks

Elastic weight consolidation

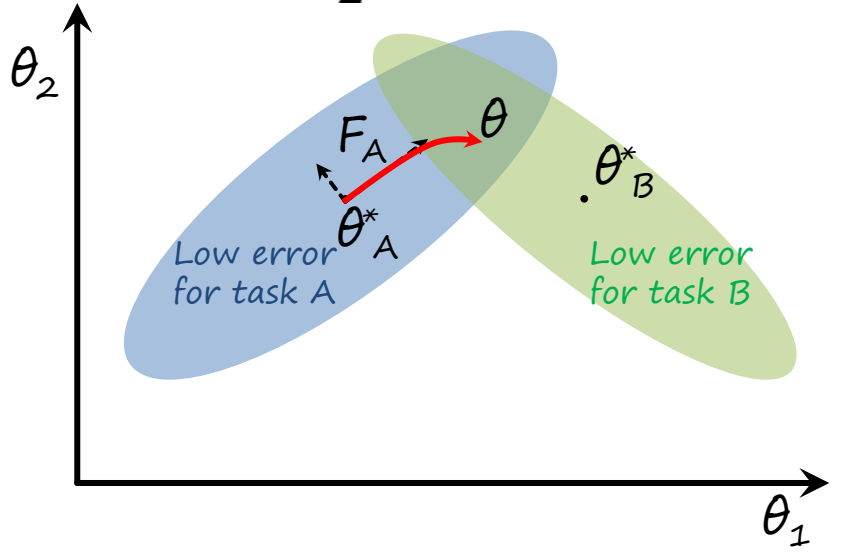
Fine tuning

$$\mathcal{L}(\theta) \approx \mathcal{L}_B(\theta)$$



Elastic weight consolidation (EWC)

$$\mathcal{L}(\theta) \approx \mathcal{L}_B(\theta) + \frac{\lambda}{2}\left(\theta - \theta^*_A\right)^\intercal F_A \left(\theta - \theta^*_A\right)$$



Problem: size of F_A is $(\#\theta)^2$

Kirkpatric et al., Overcoming catastrophic forgetting in neural networks, PNAS, 2017

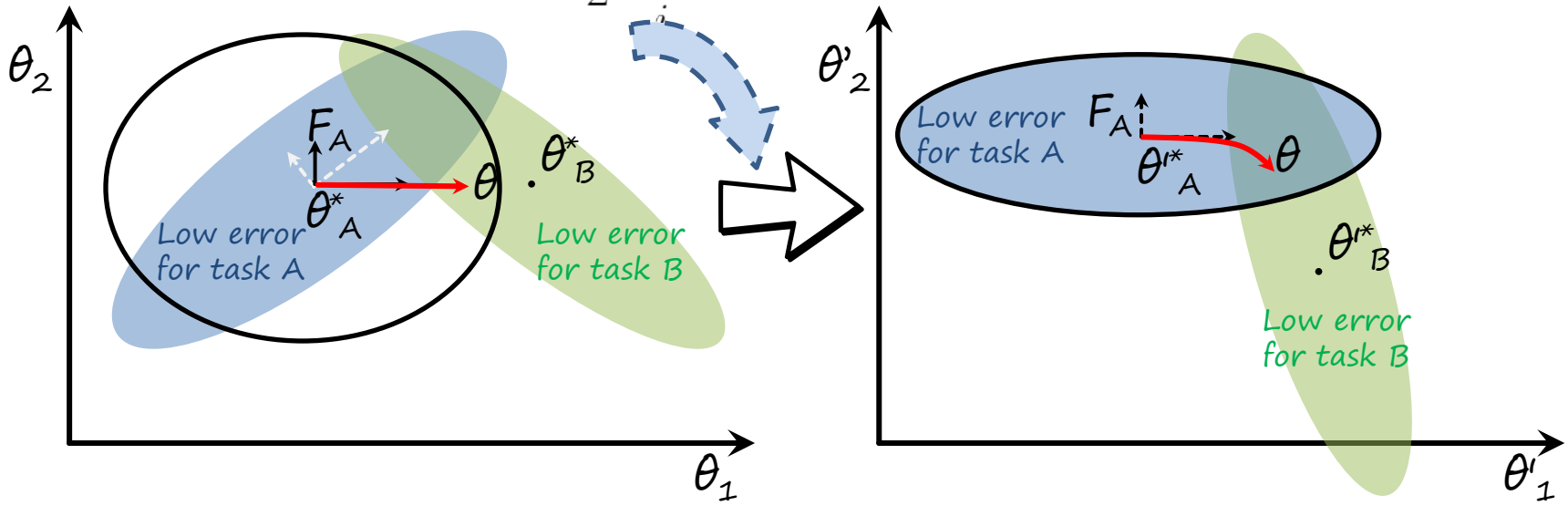
Rotated elastic weight consolidation

Size of the diagonal of F_A is #θ

Elastic weight consolidation in practice (with diagonal approx. of F_A)

Rotated elastic weight consolidation (R-EWC)

$$\mathcal{L}(\theta) \approx \mathcal{L}_B(\theta) + \frac{\lambda}{2} \sum_i F_{A_i} \left(\theta - \theta^*_A\right)^2$$



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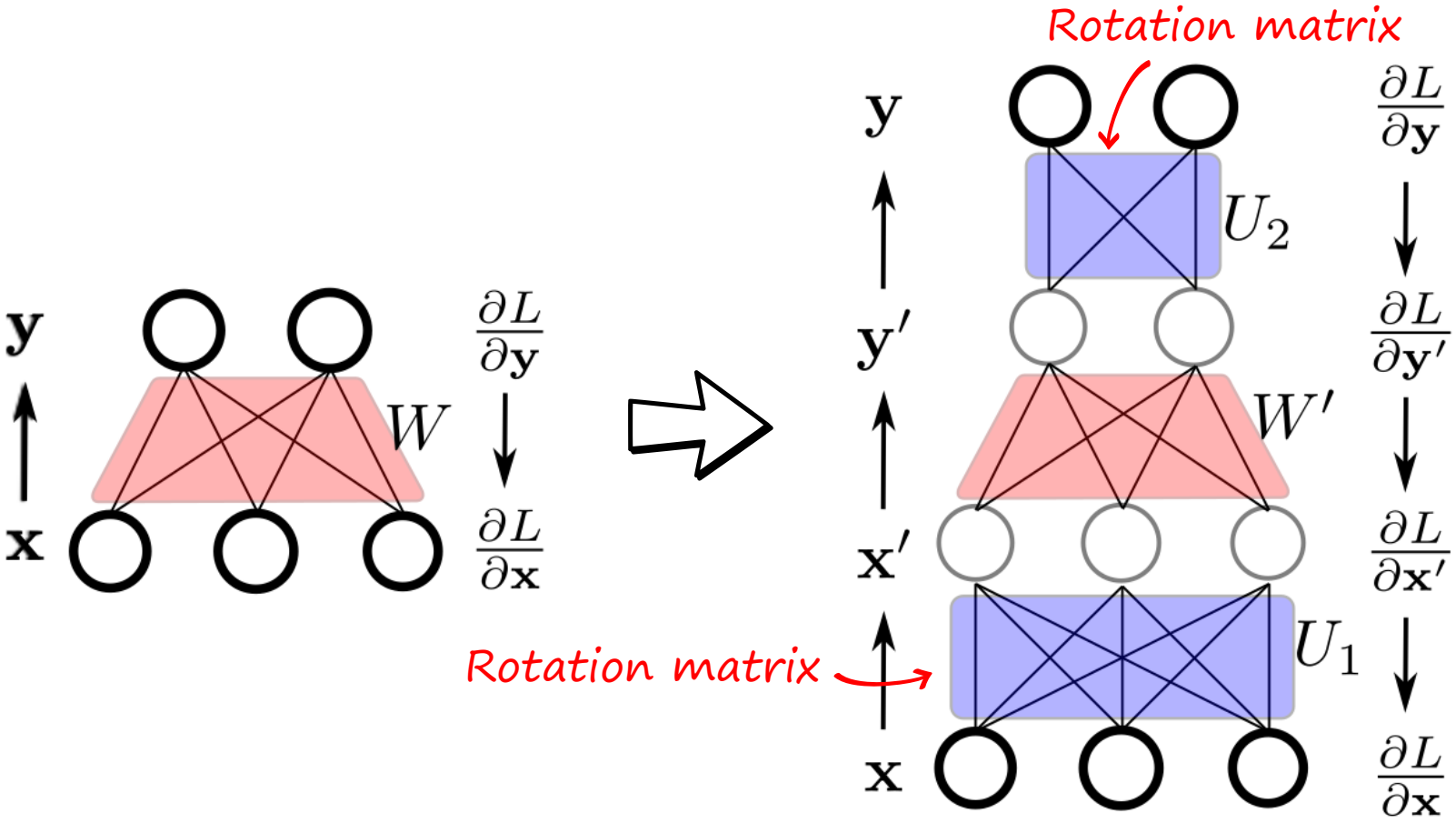
Rotating fully connected layers



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Computing the rotations

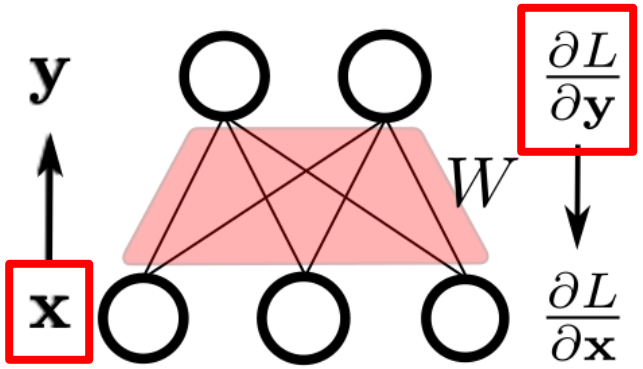
$$F_W = \mathbb{E}_{p\sim\pi}\left[\left(\frac{\partial L}{\partial \mathbf{y}}\right)\mathbf{x}\mathbf{x}^\intercal\left(\frac{\partial L}{\partial \mathbf{y}}\right)^\intercal\right]$$

$$F_W \approx \mathbb{E}_{\substack{x\sim\pi\\ y\sim p}}\left[\left(\frac{\partial L}{\partial \mathbf{y}}\right)\left(\frac{\partial L}{\partial \mathbf{y}}\right)^\intercal\right]\mathbb{E}_{x\sim\pi}\left[\mathbf{x}\mathbf{x}^\intercal\right]$$

$$\mathbb{E}_{x\sim\pi}\left[\mathbf{x}\mathbf{x}^\intercal\right] = U_1 S_1 V_1^\intercal$$

$$\mathbb{E}_{\substack{x\sim\pi\\ y\sim p}}\left[\left(\frac{\partial L}{\partial \mathbf{y}}\right)\left(\frac{\partial L}{\partial \mathbf{y}}\right)^\intercal\right] = U_2 S_2 V_2^\intercal$$

Using SVD



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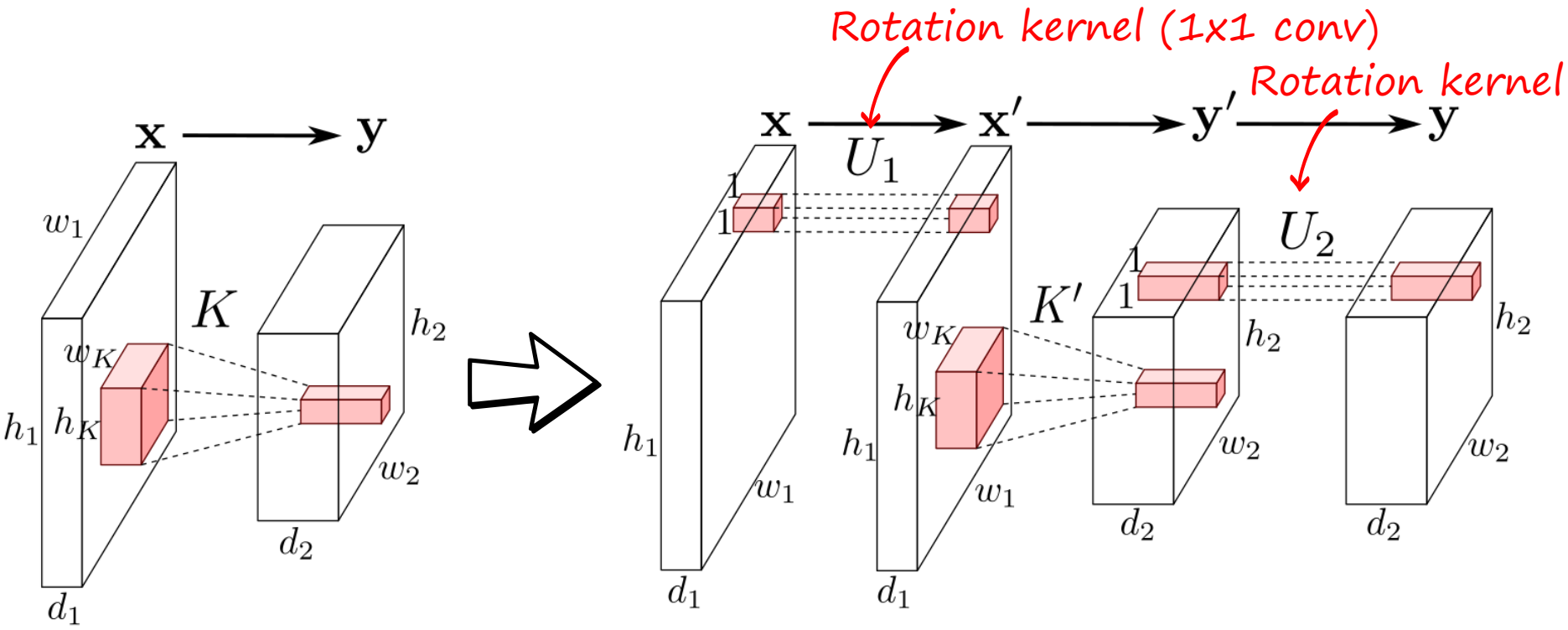
Rotating convolutional layers



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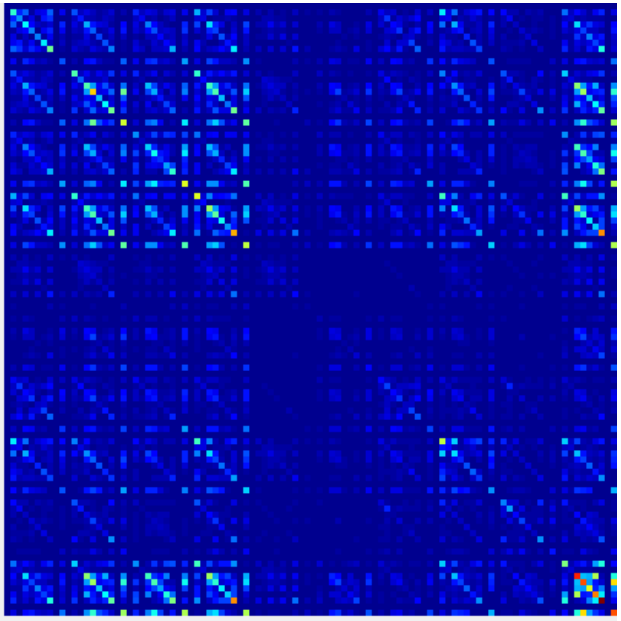
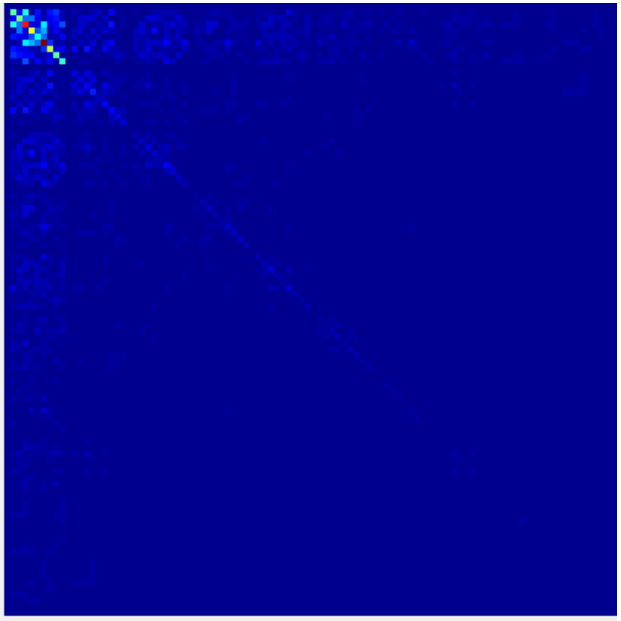
Fisher Information matrix

No rotation (i.e. EWC)



Energy in the diagonal: 40%

After rotation (i.e. R-EWC)



Energy in the diagonal: 74%

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Experimental results

- MNIST dataset. Two tasks: 0-4 and 5-9

	$\lambda = 1$		$\lambda = 10$		$\lambda = 100$		$\lambda = 1000$		$\lambda = 10000$	
	Task 1	Task 2	Task 1	Task 2	Task 1	Task 2	Task 1	Task 2	Task 1	Task 2
FT	6.1	97.6	6.1	97.6	6.1	97.6	6.1	97.6	6.1	97.6
EWC [5]	66.8	90.9	75.3	95.6	**85.8**	**92.8**	78.4	93.7	81.0	88.8
R-EWC - conv only	62.7	89.2	67.5	96.1	80.4	91.4	**84.7**	**93.1**	75.5	93.7
R-EWC - fc only	78.9	95.3	79.0	95.8	87.4	93.5	93.0	82.3	**94.3**	**88.0**
R-EWC - all	77.2	96.7	**91.7**	**91.2**	86.9	95.9	96.3	81.1	92.1	86.0
R-EWC - all no last	71.5	91.8	84.9	97.0	**91.6**	**94.5**	94.6	88.4	97.9	79.4

- Several datasets

	EWC [5] (T1 / T2)	R-EWC (T1 / T2)
MNIST	89.3 (85.8 / 92.8)	**93.1** (91.6 / 94.5)
CIFAR-100	37.5 (23.5 / 51.5)	**42.5** (30.2 / 54.7)
CUB-200 Birds	45.3 (42.3 / 48.6)	**48.4** (53.3 / 45.2)
Stanford-40 Actions	50.4 (44.3 / 58.4)	**52.5** (52.3 / 52.6)

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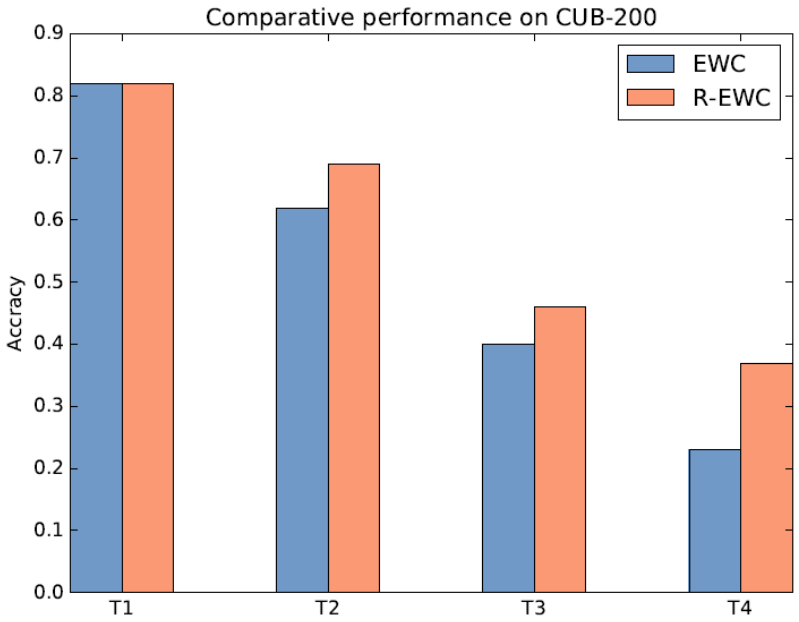
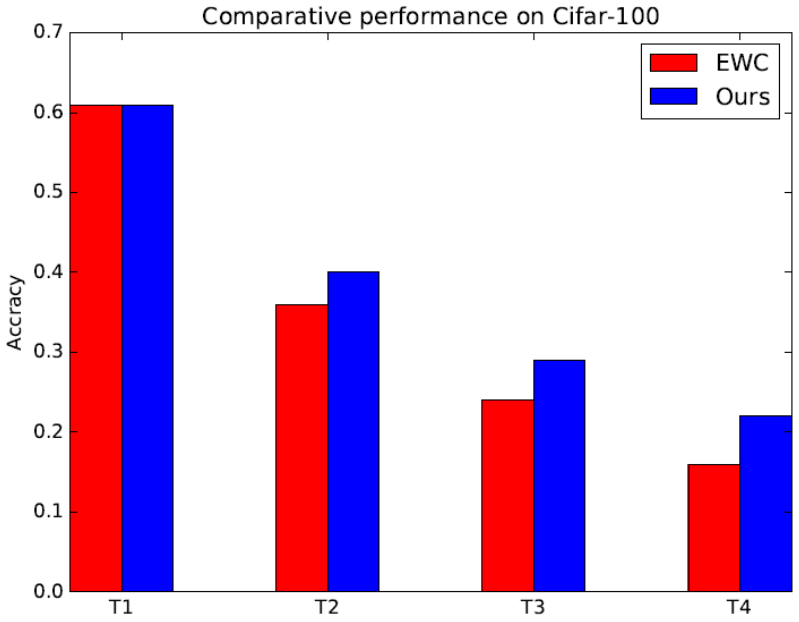
Results on 4 tasks





CUB-200 Birds

CIFAR-100

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THANK YOU!