KYUSHU UNIVERSITY

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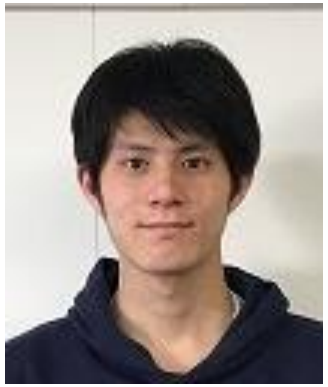
Advanced Information and Communication Technology for Innovation ACT-i

ACT-X

ICASSP 2021 TORONTO Canada
June 6-11, 2021
Metro Toronto Convention Centre

Layer-wise Interpretation of Deep Neural Networks Using Identity Initialization

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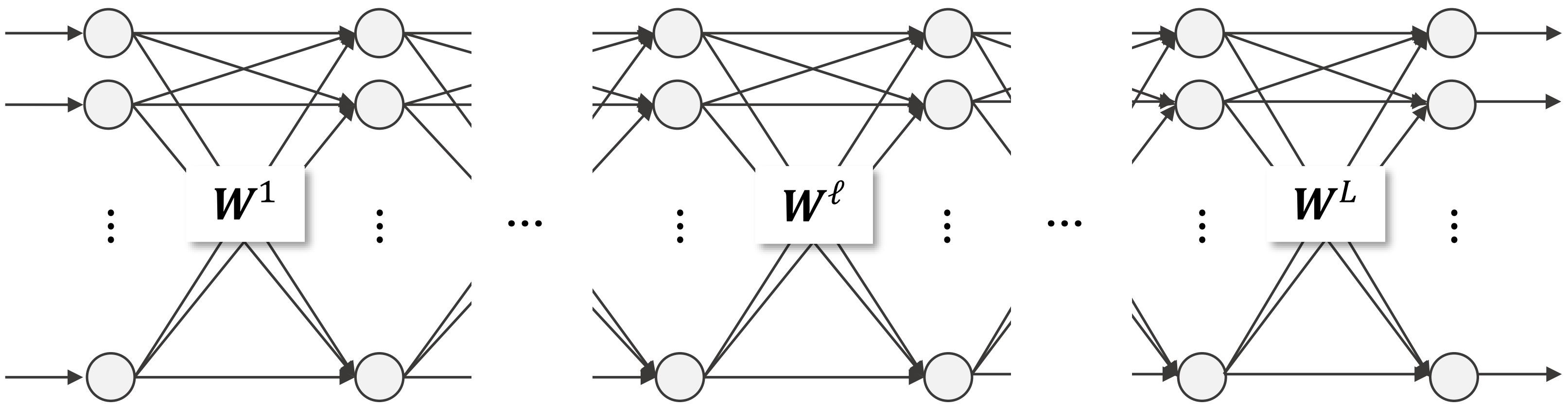
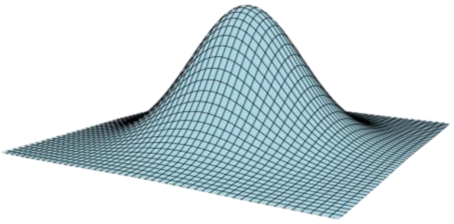
Can identity initialized deep neural nets be trained?



Standard initialization

- Random matrix

$W^\ell \sim$ 

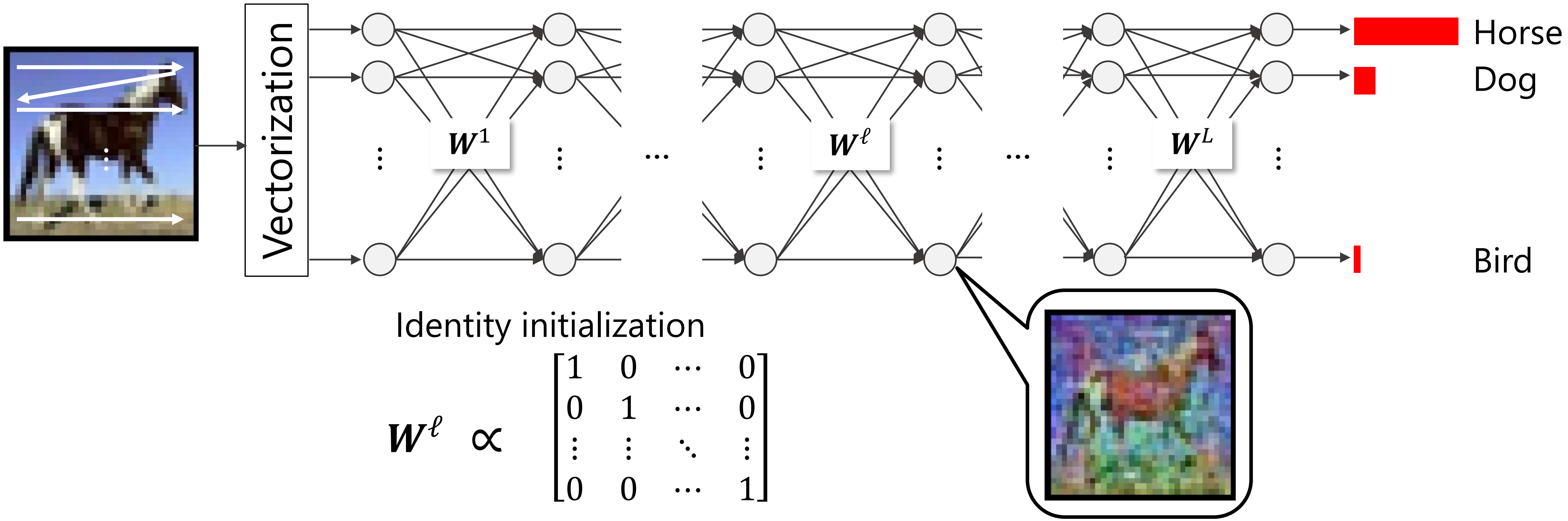
Initialization in this study

- Identity matrix

$$W^\ell \propto \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

Interpretability of the internal process

- **Learned weights are close to the identity matrix**
- **Intermediate features preserve the input structure**

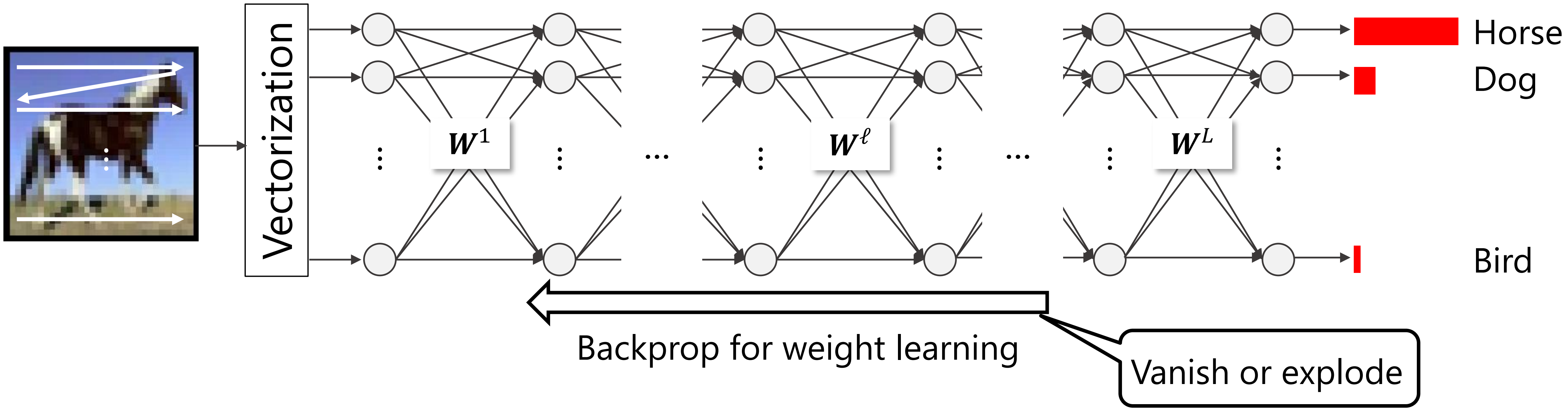


Identity initialization

$$W^\ell \propto \begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

Gradient vanishing and exploding

- **Identity-initialized deep neural networks suffer from the gradient vanishing/exploding problems**



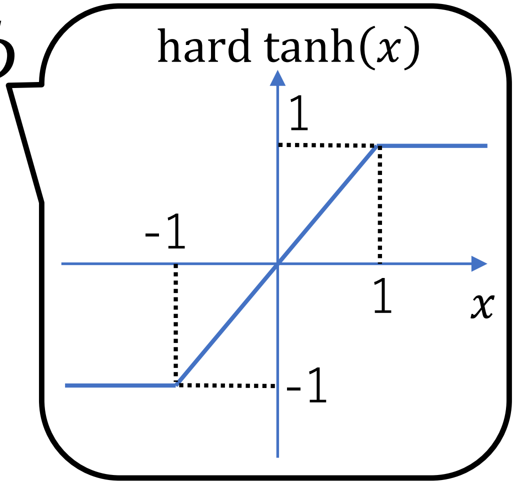
Investigate the potential of identity initialization

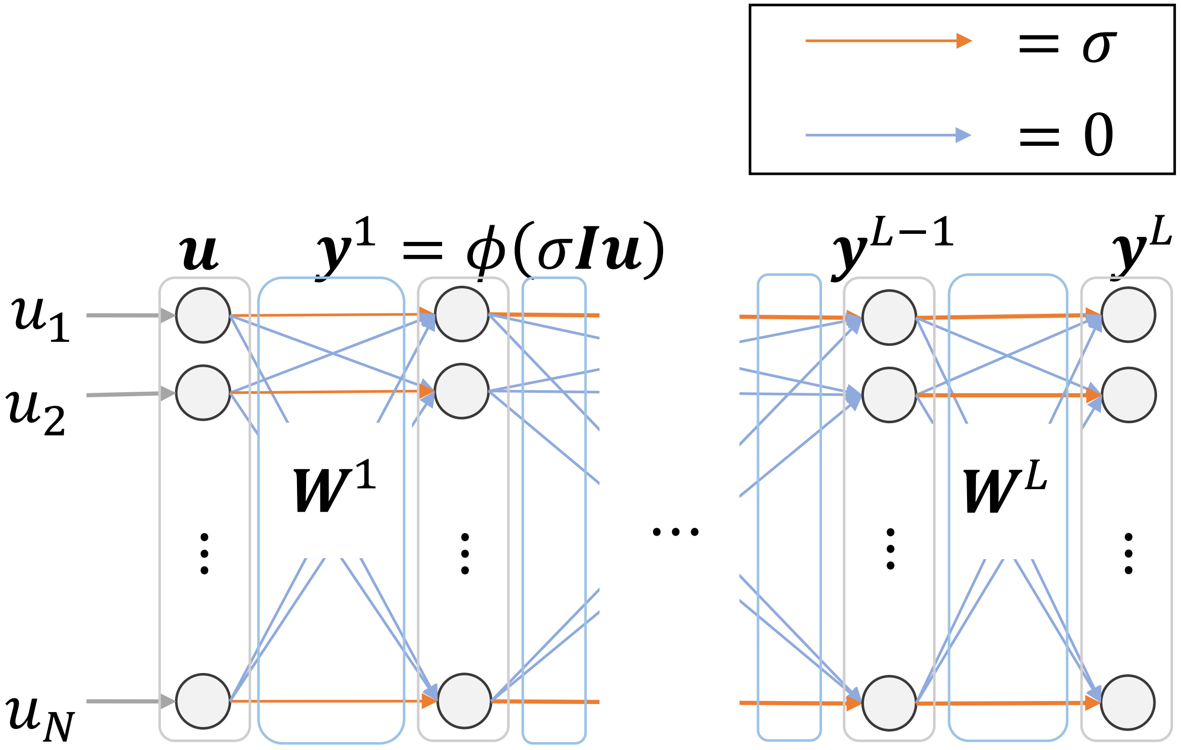
- **Theory:**
  We show a condition under which the identity-initialized deep multilayer perceptron (MLP) prevents gradient vanishing/exploding.

- **Application:**
  We propose an interpretable MLP structure using identity initialization.

Identity initialization

- **MLP of L layers with width N and $\boldsymbol{W}^\ell \in \mathbb{R}^{N\times N}$**
- **Initialization: $\boldsymbol{W}^\ell = \sigma \boldsymbol{I}$**
- **Activation ϕ**





$\boldsymbol{W}^\ell = \sigma \boldsymbol{I}$

- **Input u follows $N(0, q^0)$**

Condition to prevent gradient vanishing/exploding

Dynamical isometry

- **Singular values of Jacobian J (or eigenvalues of $J^{\mathrm{T}}J$) concentrate around 1**

Output

$$J = \frac{\partial \boldsymbol{y}^L}{\partial \underline{\boldsymbol{u}}} = \boldsymbol{D}^1 \underline{\boldsymbol{W}^1} \boldsymbol{D}^2 \boldsymbol{W}^2 \cdots \underline{\boldsymbol{D}^L} \boldsymbol{W}^L$$

Input

Weight of the first layer

Derivative of the activation function at the L-th layer

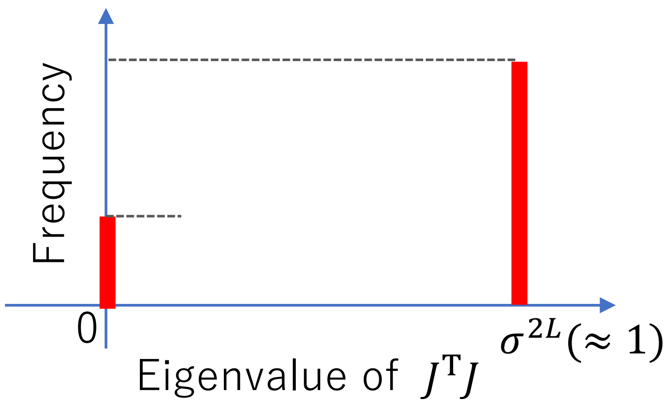
Theoretical result

- **The eigenvalue distribution is a Bernoulli function**

$$\mu_{JJ^{\top}}(\lambda) = \begin{cases} \alpha^L\,\delta(\lambda - \sigma^{2L}) - (1 - \alpha^L)\,\delta(\lambda) & (\sigma > 1) \\ \alpha^1\delta(\lambda - \sigma^{2L}) - (1 - \alpha^1)\,\delta(\lambda) & (\sigma \leq 1) \end{cases}$$

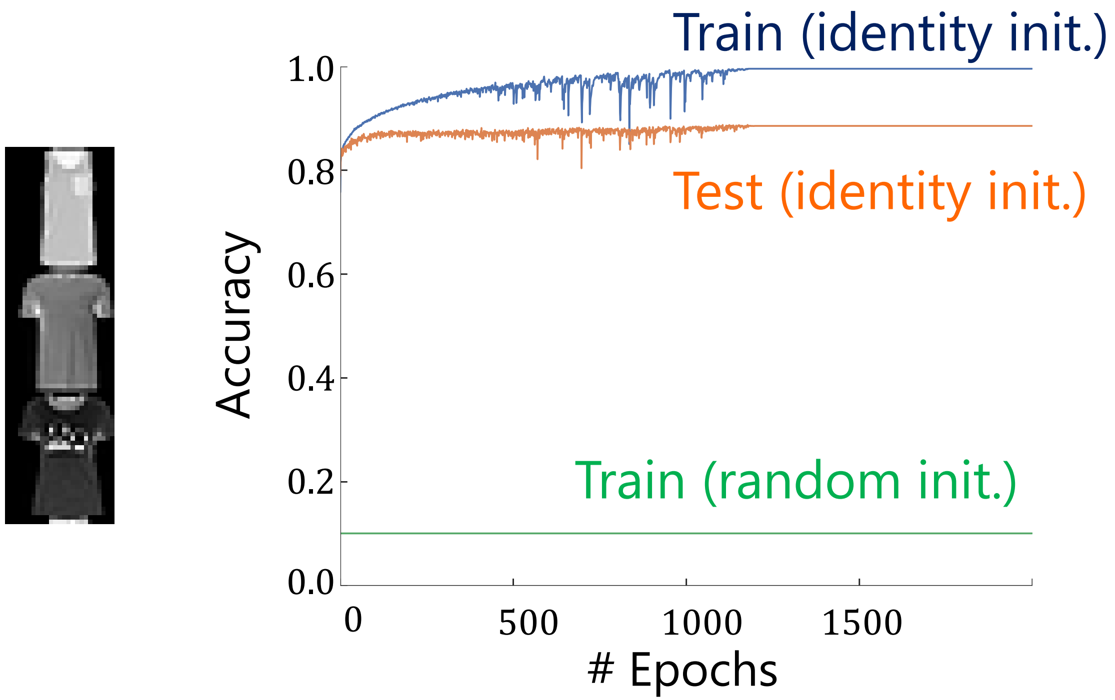
α^{ℓ}: Constant depending on σ (constant) and q^0 (input variance)

- **We can prevent gradient vanishing by setting σ and q^0 appropreately**

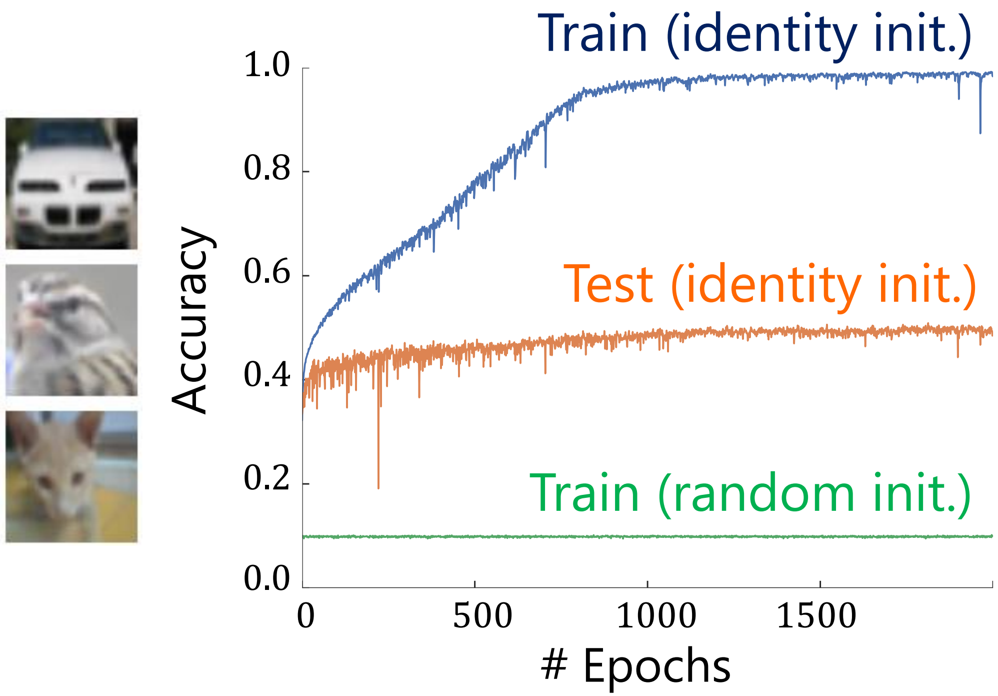


Identity-initialized networks can be trained

- **MLP with 100 layers**
- **Dataset: Fashion-MNIST and CIFAR-10 (10 classes)**



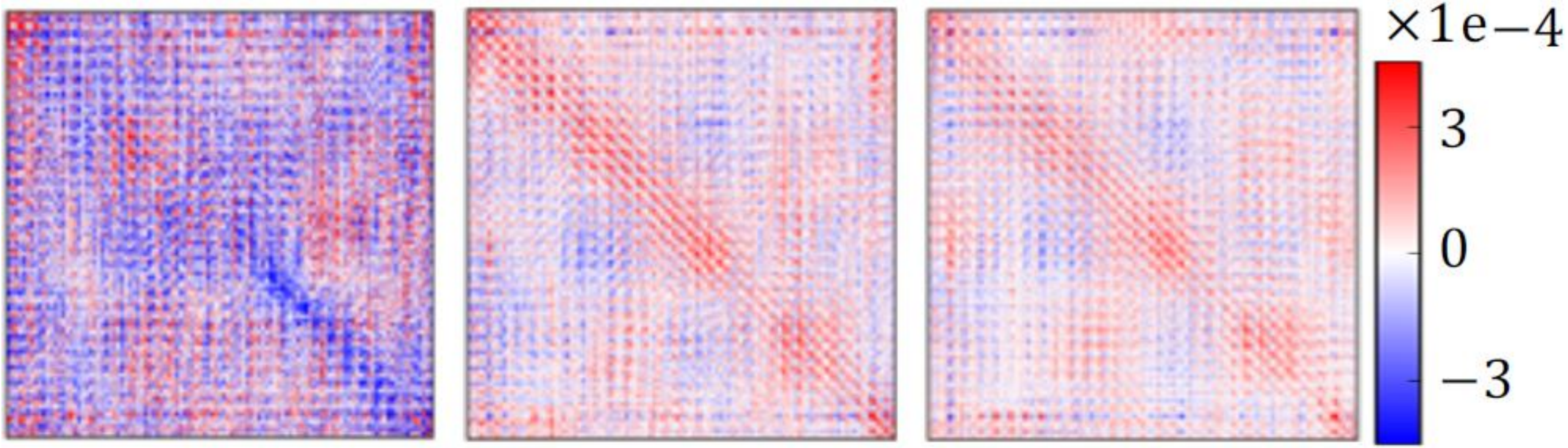
(a) Fashion-MNIST



(b) CIFAR-10

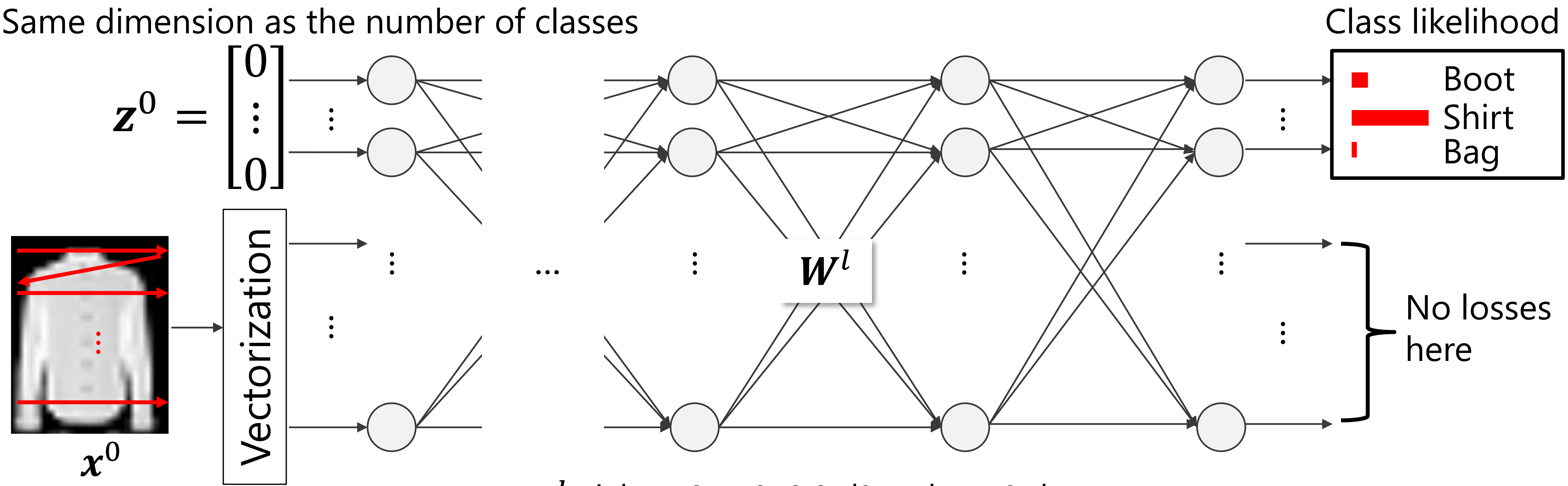
Close to the identity matrix

- **Difference of the weight matrix from the identity matrix after training**



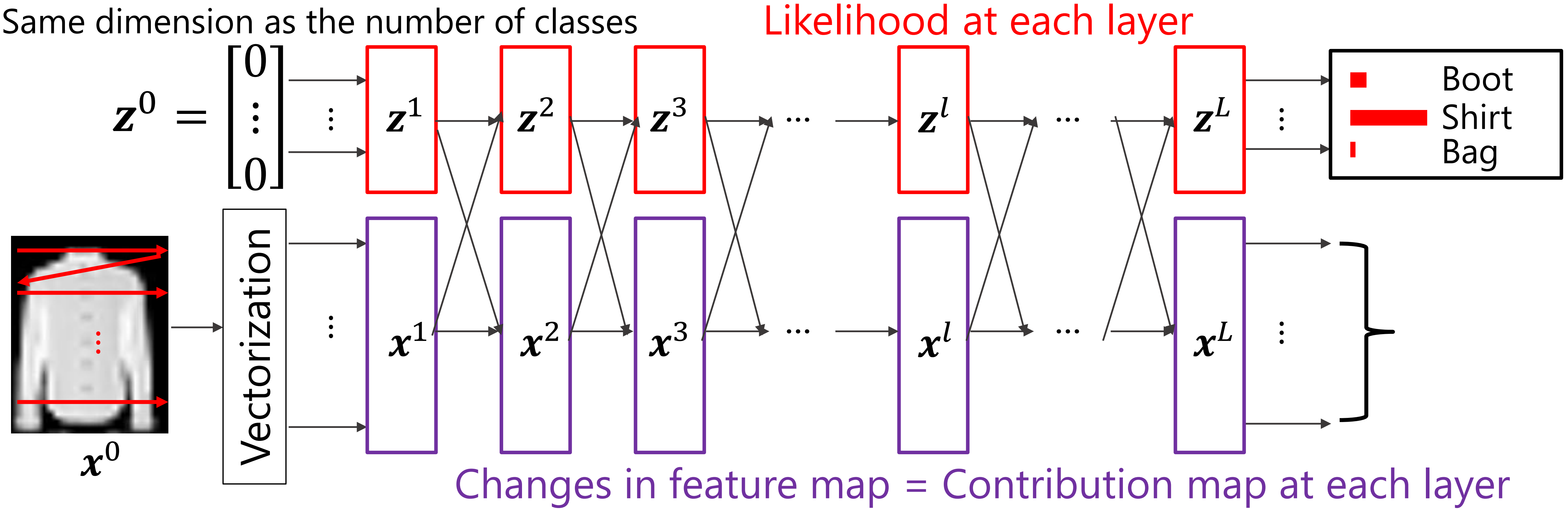
10th layer　　40th layer　　100th layer

Network structure that enhances interpretability

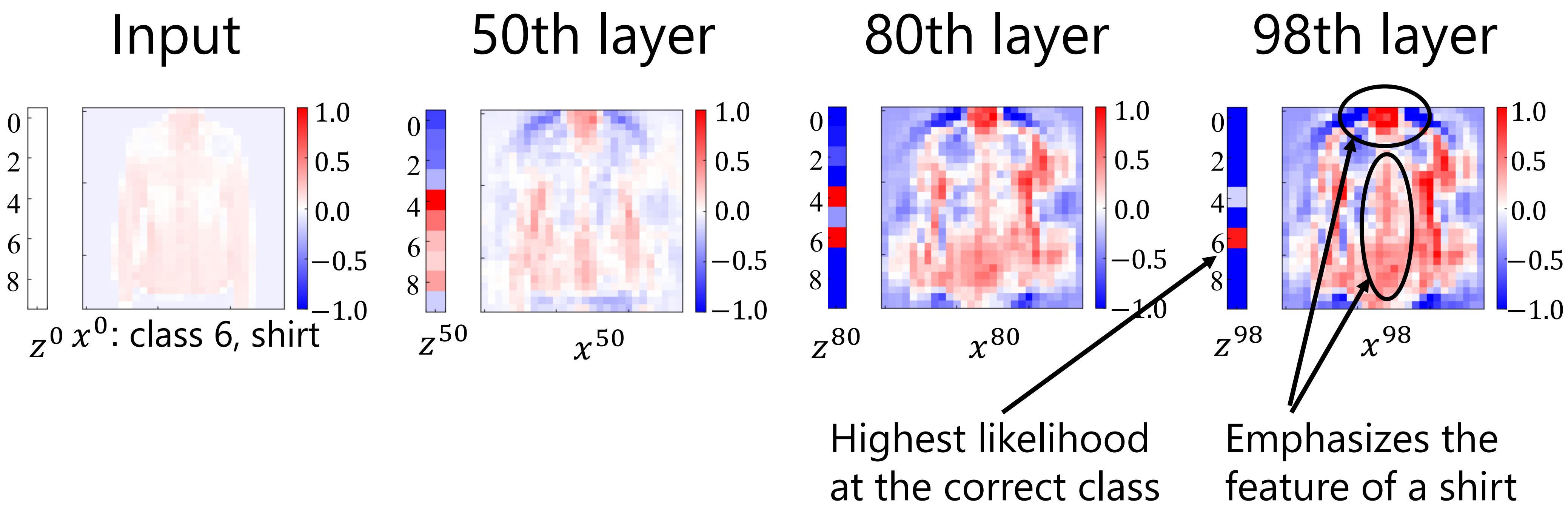


W^l: Identity-initialized weight

Network structure that enhances interpretability



Emphasize the areas important for classification



0: T-shirt
1: Trouser
2: Pullover
3: Dress
4: Coat
5: Sandal
6: Shirt
7: Sneaker
8: Bag
9: Ankle boot

z^l: Class likelihood at l-th layer
x^l: Feature map at l-th layer

Conclusion

- **Investigate the potential of identity initialization**
  - Condition for preventing the vanishing/exploding gradients
  - Network structure enhancing interpretability

- **Future work**
  - Analysis of changes in feature values during learning
  - Application to other structures such as convolutional neural networks

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Shohei Kubota, Hideaki Hayashi, Tomohiro Hayase, and Seiichi Uchida

Poster Session

MLSP-42: Neural Network Pruning

Friday, 11 June from 11:30 to 12:15 (EDT)