Federal University of São Carlos
Physics Department
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Local Feature Alignment for Efficient TinyML Training on Low-Power Devices

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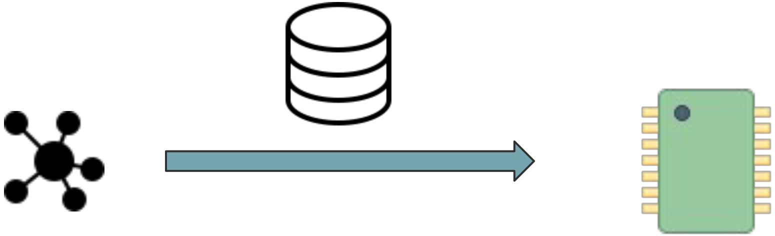
Model
Training
Inference

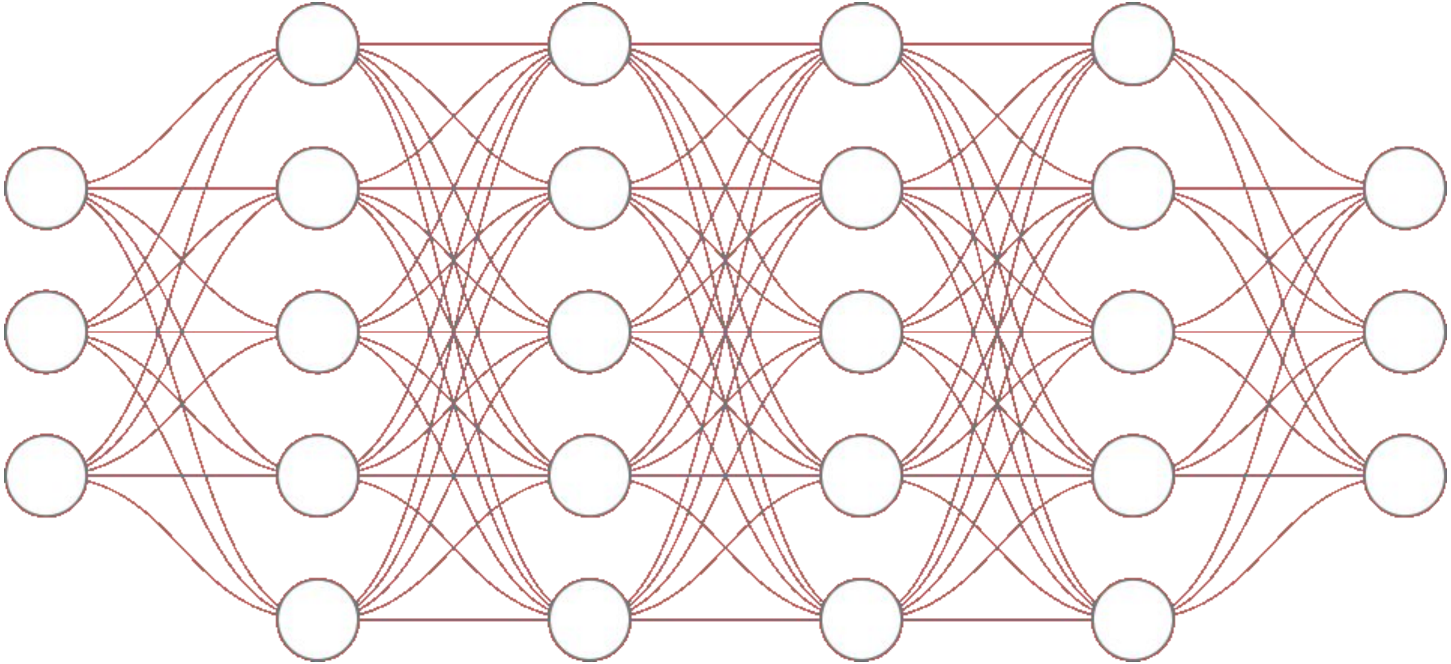


Model

Training and/or inference

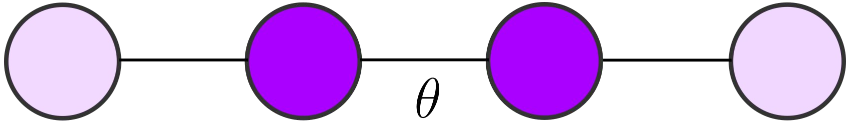
Learning rules for neural networks

Global learning rules

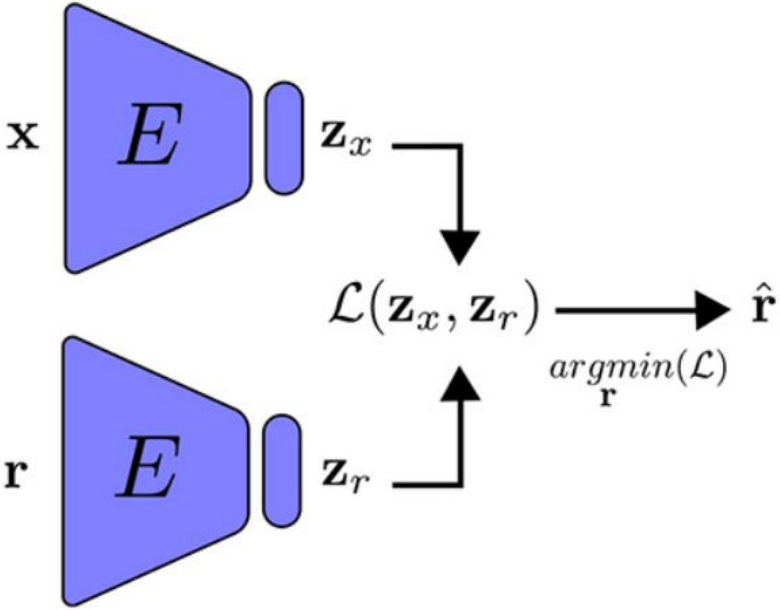


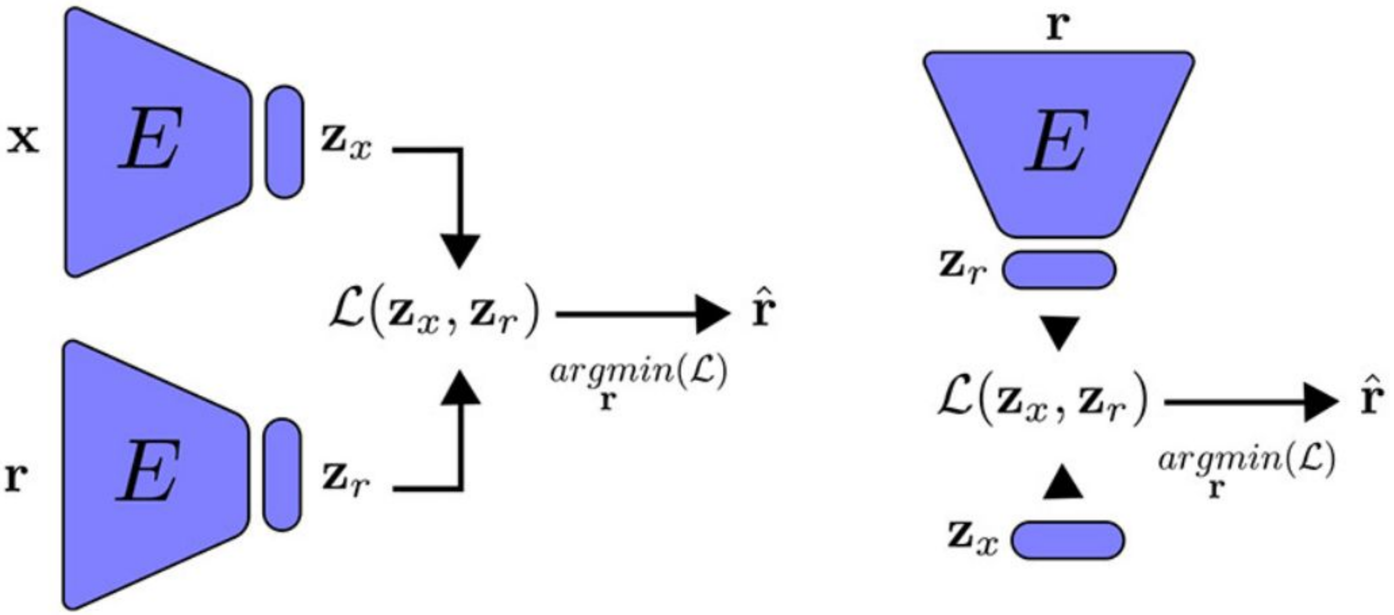
Local learning rules

"Neurons that fire together wire together."
Donald O. Hebb



Feature Alignment

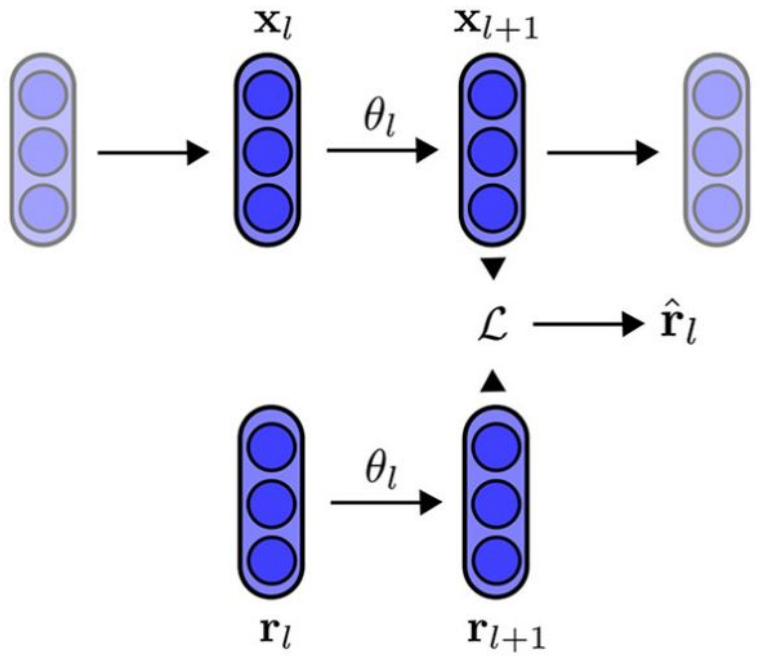

x
E
$\mathbf{z}_x$
r
E
$\mathbf{z}_r$
$\mathcal{L}(\mathbf{z}_x, \mathbf{z}_r)$
$\hat{\mathbf{r}}$
$\underset{\mathbf{r}}{argmin}(\mathcal{L})$



x
E
$\mathbf{z}_x$
r
E
$\mathbf{z}_r$
$\mathcal{L}(\mathbf{z}_x, \mathbf{z}_r)$
$\hat{\mathbf{r}}$
$\underset{\mathbf{r}}{argmin}(\mathcal{L})$
r
E
$\mathbf{z}_r$
$\mathcal{L}(\mathbf{z}_x, \mathbf{z}_r)$
$\hat{\mathbf{r}}$
$\underset{\mathbf{r}}{argmin}(\mathcal{L})$
$\mathbf{z}_x$

Local Feature Alignment

Training Locally



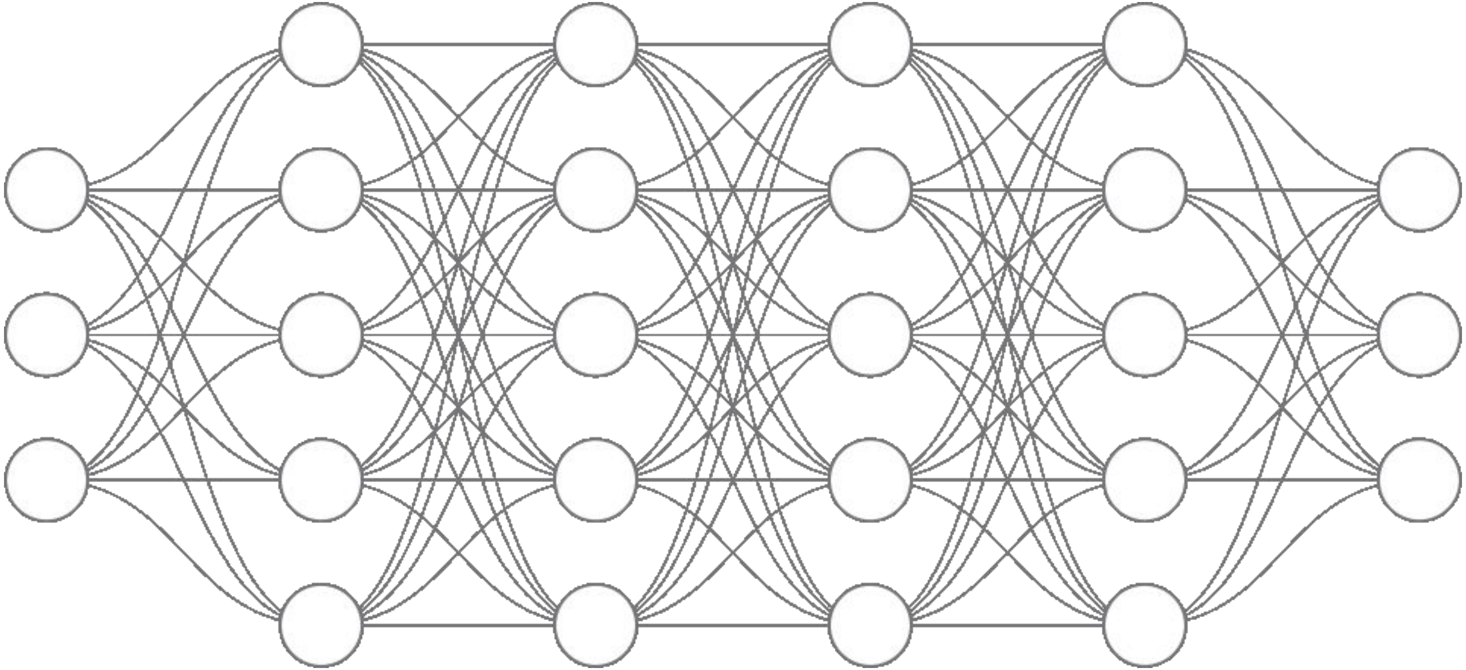
$$\mathcal{L} = ||x_{l+1} - r_{l+1}||_2^2$$

$$\hat{x}_l = -\frac{\partial \mathcal{L}}{\partial r_l}$$

$$\mathcal{C} = ||x_l - r_l||_2^2$$

$$\Delta\theta \leftarrow -\frac{\partial \mathcal{C}}{\partial \theta_l}$$

Training Locally

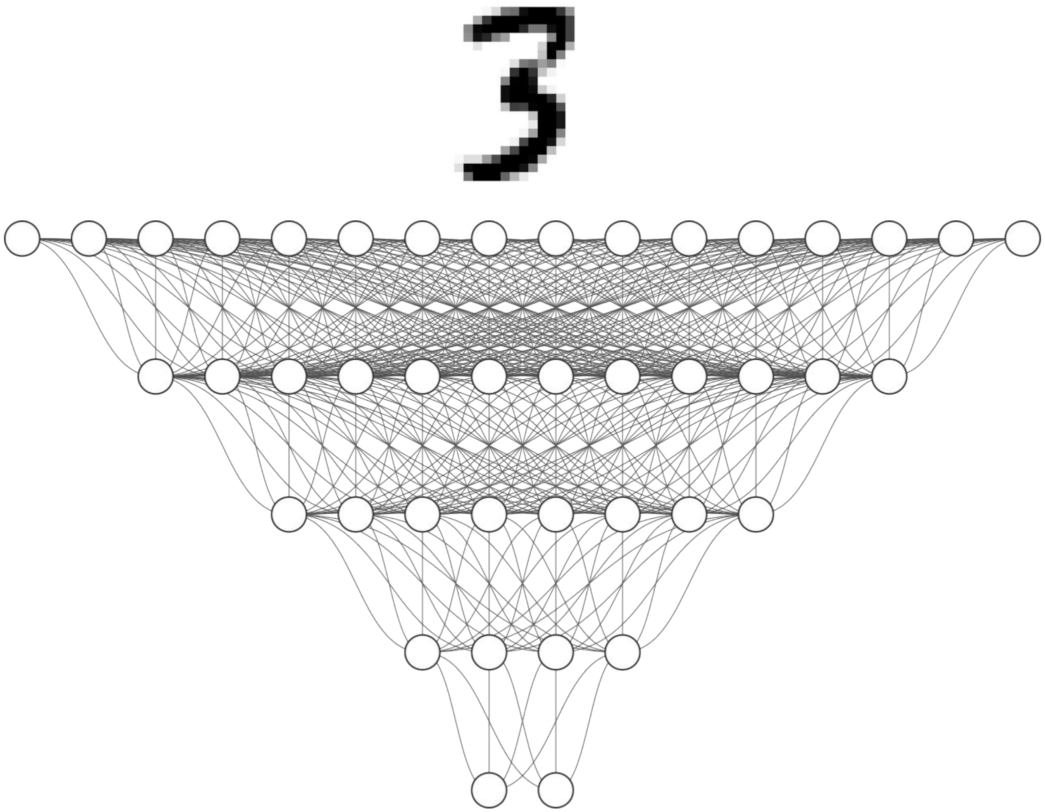


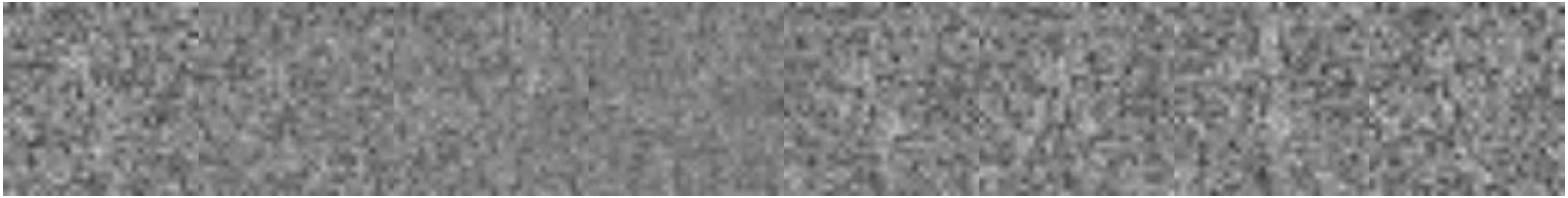
Spatial Complexity

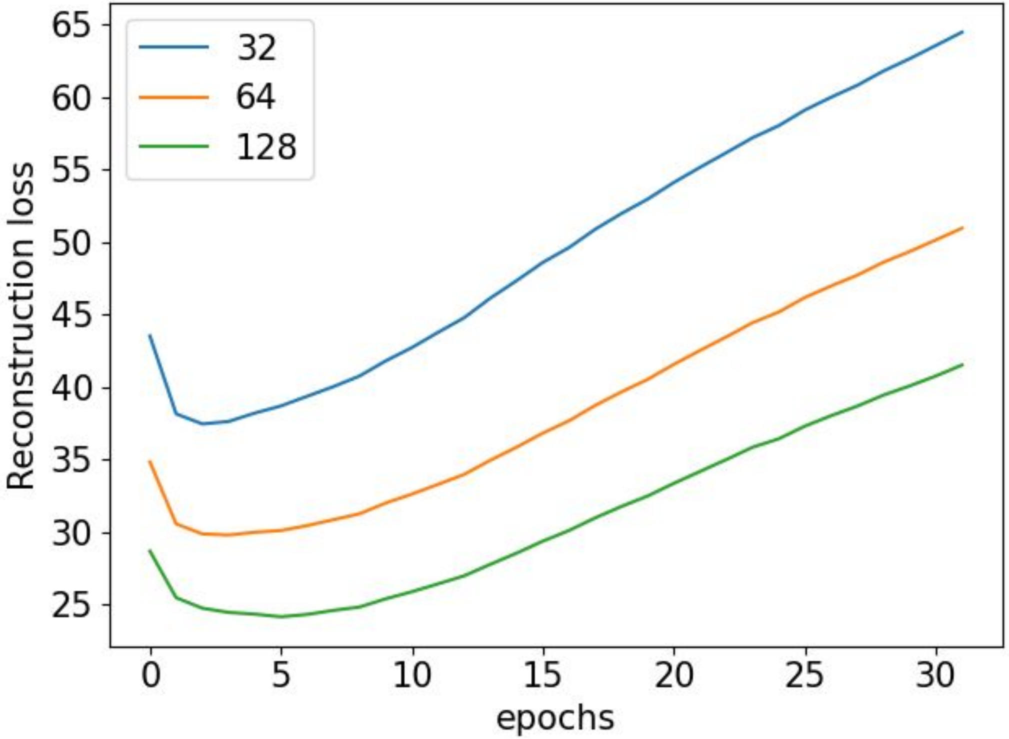
Global Learning	Local Learning
$O(LN)$	$O(N)$

Results

Network

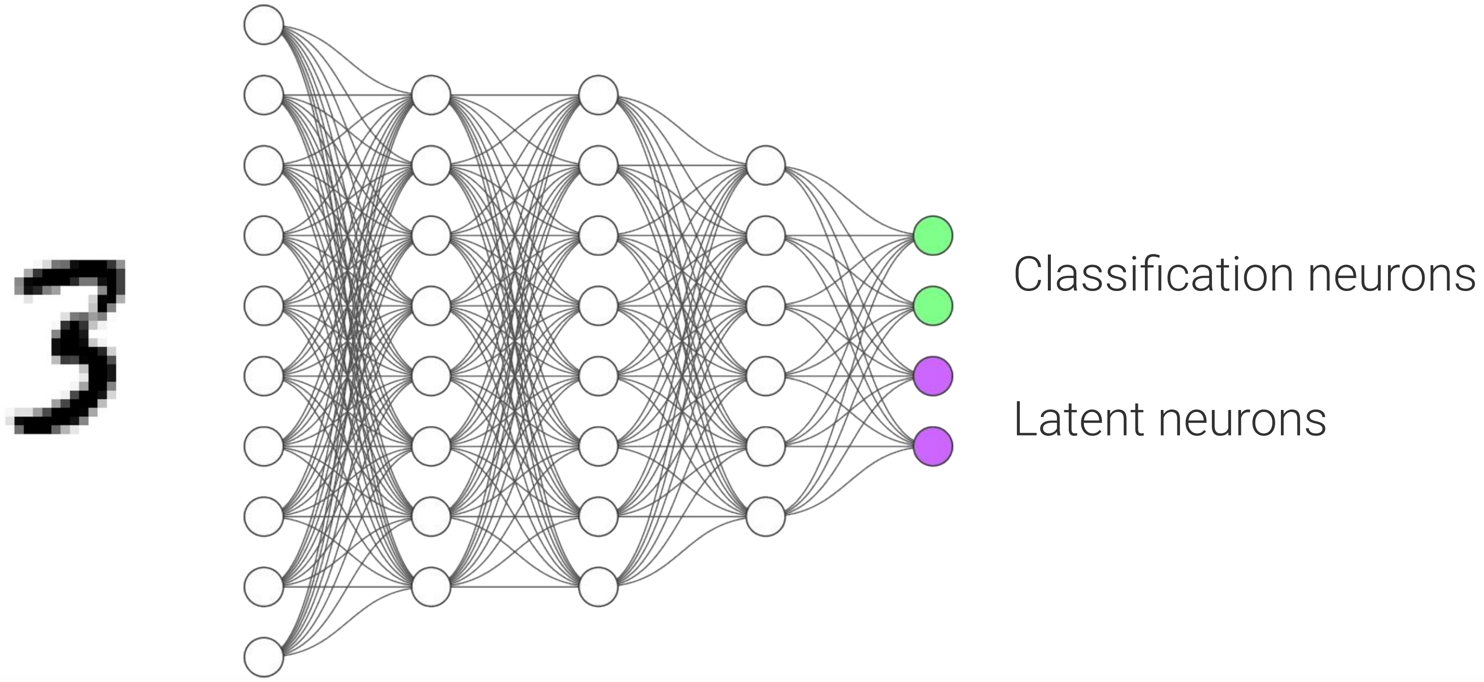




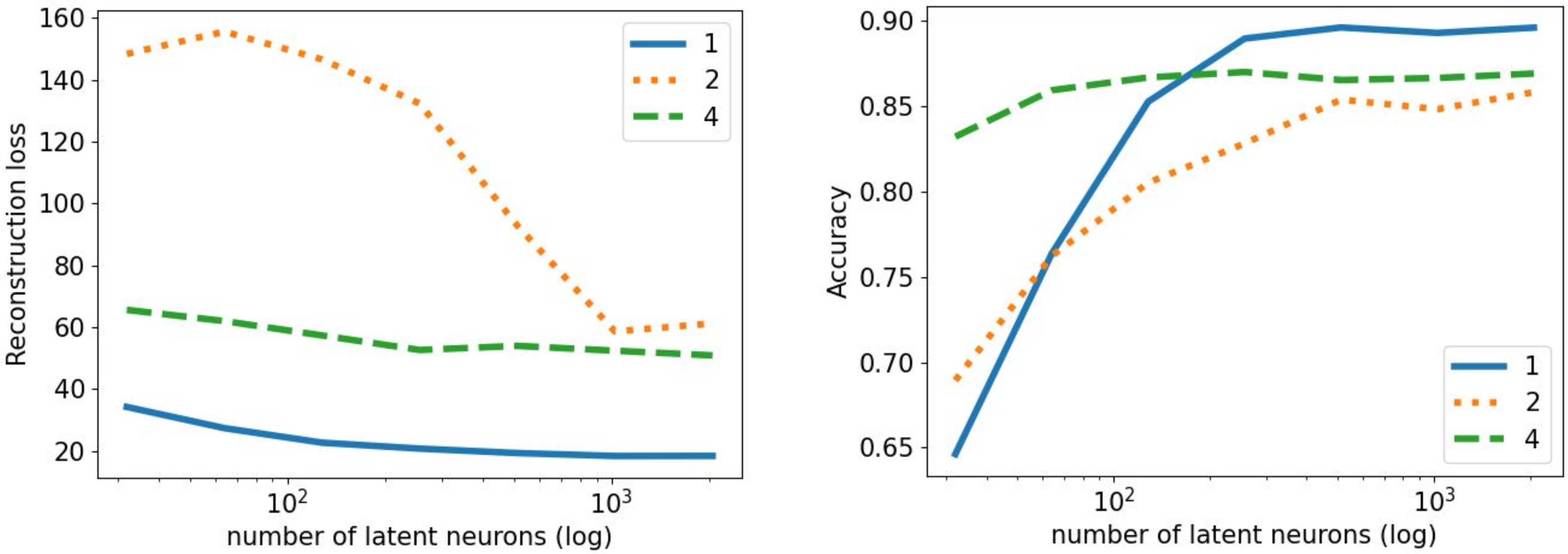


32
64
128
Reconstruction loss
65
60
55
50
45
40
35
30
25
0
5
10
15
20
25
30
epochs

Network



Test Set



Reconstruction loss
160
140
120
100
80
60
40
20
10^2
10^3
number of latent neurons (log)
1
2
4
Accuracy
0.90
0.85
0.80
0.75
0.70
0.65
10^2
10^3
number of latent neurons (log)
1
2
4

Conclusions

- We adapted the feature alignment technique to train neural networks locally;

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- We demonstrated that it can train MLPs on regression and classification problem of the MNIST;

Future Scope

- Improve feature approximation;

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- Different network architectures;

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- Other problems and datasets;

- Improve feature approximation;
- Different network architectures;
- Other problems and datasets;
- Train neural networks on real resource-constrained devices.

Farias, Tiago de Souza, and Jonas Maziero. "Feature Alignment as a Generative Process." *Frontiers in Artificial Intelligence*, vol. 5, Jan. 2023. *Frontiers*, https://doi.org/10.3389/frai.2022.1025148.

Thanks!

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