QIFK2023 **123**

NeFL: Nested Federated Learning for Heterogeneous Clients

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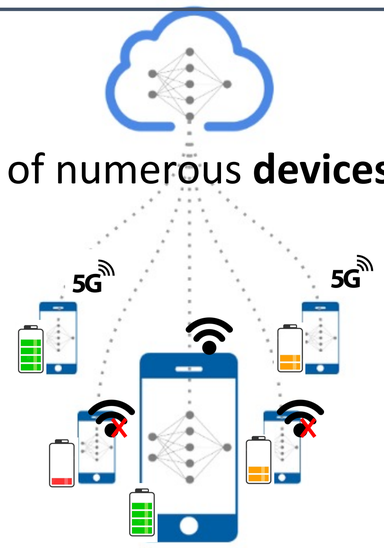
Federated Learning & On-device AI

- Federated Learning
  - Employing **computing resources & data** of numerous **devices**
  - AI is being employed on devices
- System Heterogeneity
  - Computation (CPU/GPU/ASIC)
  - Communication (4G/5G/Wi-Fi)
  - Battery (low/high)
  - Memory (trust-zone)

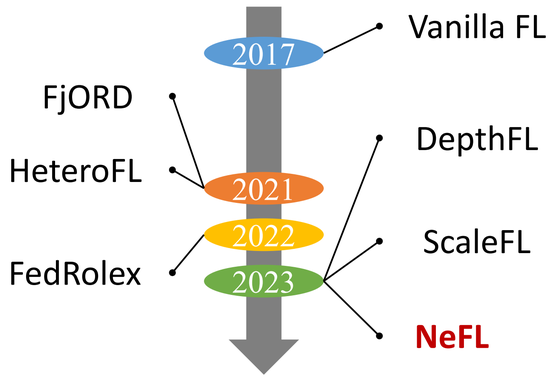


Model Scaling Approaches

Widthwise scaling
- FjORD/HeteroFL/FedRolex

Depthwise scaling
- DepthFL

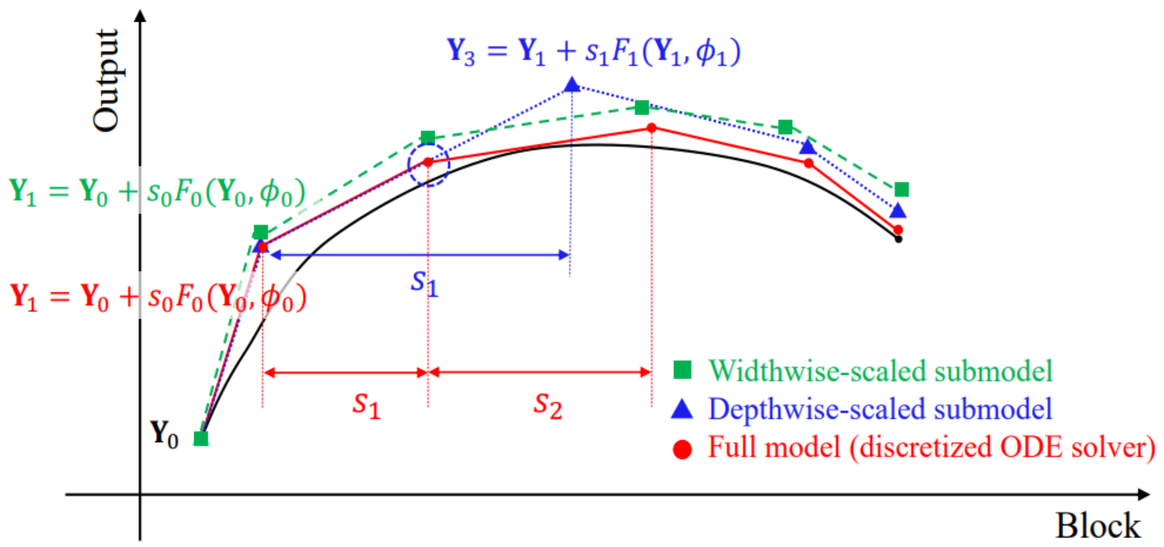
Widthwise & depthwise scaling
- ScaleFL/**NeFL (ours)**

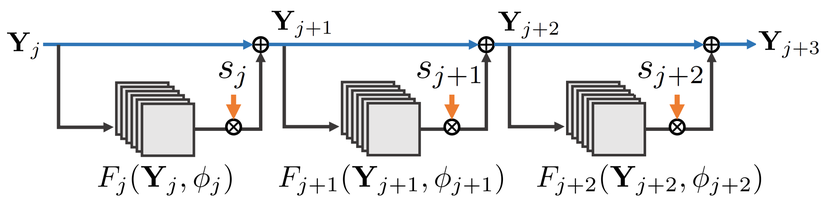


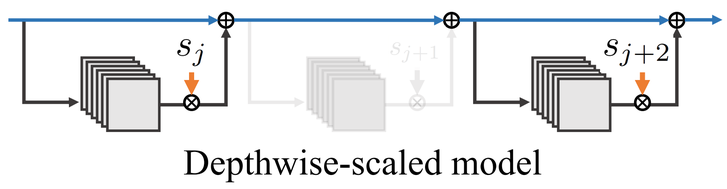
Contributions

- We propose a **general model scaling method** employing the concept of ODE solver to deal with the **system heterogeneity**
- We propose a method for **parameter averaging** across generally scaled submodels
- We evaluate the performance of NeFL through a series of experiments and verify the applicability of NeFL over recent studies (**pre-training & statistical heterogeneity**)

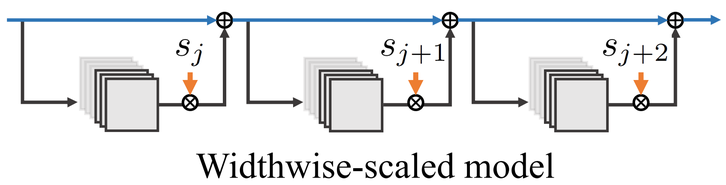
ODE Interpretation for Model Scaling





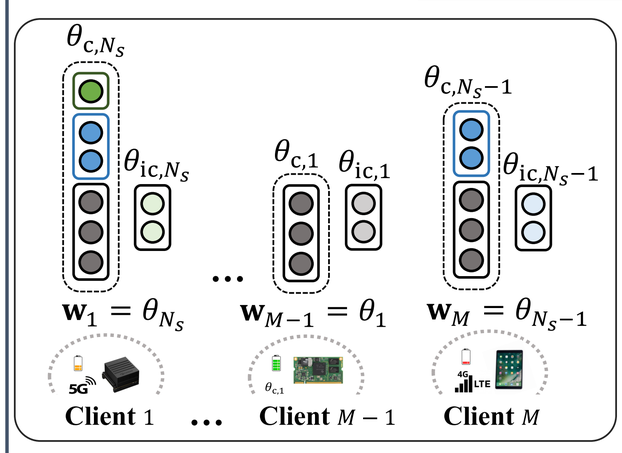


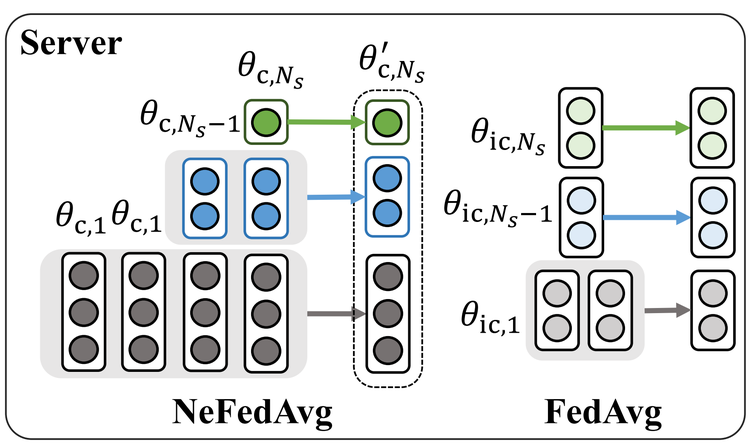
Depthwise-scaled model



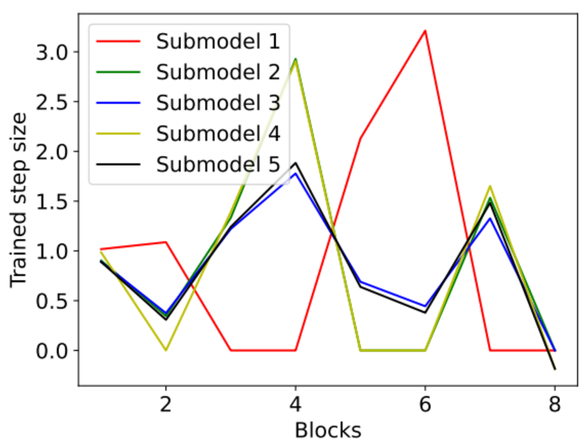
Widthwise-scaled model

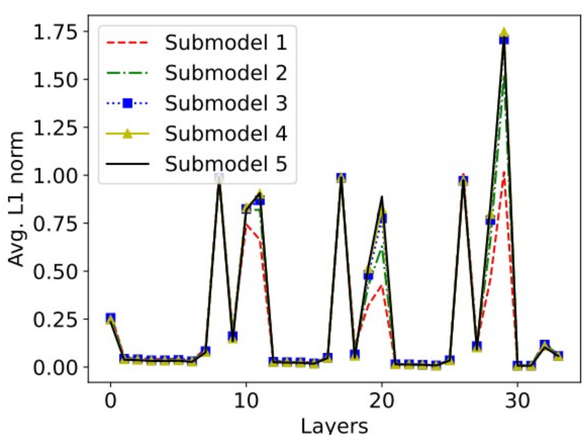
Parameter Averaging





Inconsistent/consistent Parameters





Results

Model	Method	IID		non-IID	
		Worst	Avg	Worst	Avg
ResNet18	HeteroFL	80.62 (± 0.24)	84.26 (± 1.95)	76.25 (± 1.05)	80.11 (± 2.03)
	FjORD	85.12 (± 0.22)	87.32 (± 1.21)	75.81 (± 5.65)	77.99 (± 6.50)
	DepthFL	64.80 (± 10.49)	82.44 (± 10.17)	59.61 (± 5.16)	76.89 (± 9.60)
	NeFL (ours)	**86.86 (± 0.22)**	**87.88 (± 0.68)**	**81.26 (± 2.44)**	**81.71 (± 3.14)**

Model	Method	IID		non-IID	
		Worst	Avg	Worst	Avg
Pre-trained ResNet18	HeteroFL	78.26 (± 0.15)	84.48 (± 3.04)	71.95 (± 1.32)	76.17 (± 3.39)
	FjORD	86.37 (± 0.18)	88.91 (± 1.37)	81.81 (± 1.10)	81.96 (± 5.76)
	DepthFL	47.76 (± 8.54)	82.86 (± 17.98)	39.78 (± 3.74)	67.71 (± 16.88)
	NeFL (ours)	**88.61 (± 0.08)**	**89.60 (± 0.70)**	**82.91 (± 0.47)**	**85.85 (± 2.43)**

Model	Param. #	IID		non-IID	
		Worst	Avg	Worst	Avg
Pre-trained ViT	86.4M	93.02 (± 0.06)	95.96 (± 2.10)	87.56 (± 0.16)	92.74 (± 3.95)
Pre-trained Wide ResNet101	124.8M	90.9 (± 0.16)	91.35 (± 0.39)	87.17 (± 0.04)	87.74 (± 1.06)

	Depthwise	Widthwise	Step size
DepthFL	✓		
FjORD / HeteroFL		✓	
NeFL-D	✓		✓
NeFL-W		✓	✓
NeFL-WD	✓	✓	✓

Method	Worst	Avg.
HeteroFL	80.62	84.26
FjORD	85.12	87.32
NeFL-W (ours)	**85.13**	**87.36**

Method	Worst	Avg.
DepthFL	64.80	82.44
NeFL-D (ours)	**86.06**	**87.94**

Method	Worst	Avg.
NeFL-WD (ours)	**86.86**	**87.88**

Model	Metric	Method		
		Width/Depthwise scaling	Widthwise scaling	Depthwise scaling
ResNet18	Param #	6.71M	6.71M	6.68M
	FLOPs	87.8M	85M	102M