9.S912 Principles of Neural Computation in Minds and Machines

Novel task learning by **Distributed** vs. **Specialized** neural computation architectures

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Motivation

- Human brains can learn and infer novel features about familiar objects.

Hemolymph

No Hemolymph

Hemolymph?

- **To what extent does a distributed computation strategy support this ability?**
- **Hypothesis:** distributed computation serves as a better prior for a neural network to learn new features, compared to feature-specialized computation.

Data

IMAGENET

ImageNet-1k

https://www.image-net.org/

Animal Information Dataset

https://www.kaggle.com/datasets/iamsouravbanerjee/animal-information-dataset

Animal Information Dataset

Animal	Height (cm)	Weight (kg)	Color	Lifespan (years)	Diet
196 unique values	70-90 2% 200-250 2% Other (197) 96%	Up to 0.5 2% 3-8 1% Other (198) 97%	Various 7% Black, White 6% Other (179) 87%	10-15 10% 20-30 5% Other (173) 84%	Carnivore Herbivore Other (79)
Aardvark	105-120	40-65	Grey	20-30	Insectiv
Aardwolf	40-50	8-14	Yellow-brown	10-12	Insectiv
African Elephant	270-310	2700-6000	Grey	60-70	Herbivor
African Lion	80-110	120-250	Tan	10-14	Carnivor
African Wild Dog	75-80	18-36	Multicolored	10-12	Carnivor
Alpine Ibex	67-101	19-120	Brown	15-20	Herbivor
Amazon Rainforest Frog	2-13	Up to 0.5	Various	4-17	Insectiv
American Bison	152-186	318-1,000	Brown	15-20	Herbivor
Anteater	52-91	22-41	Brown, White	15-20	Insectiv
Arabian Horse	140-160	300-1000	Various	25-30	Herbivor

The overlap of two datasets:

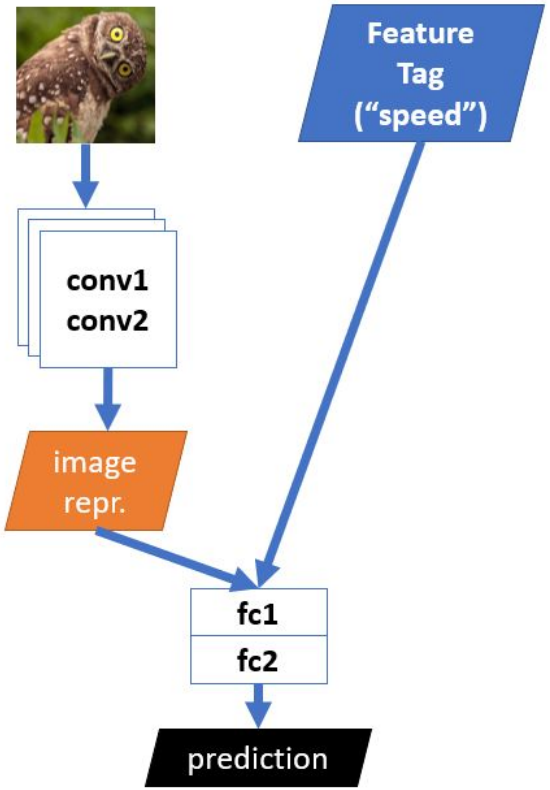
- 58,289 images
- 45 animals
- Average close to 1300 224x224 images per animal

Plan

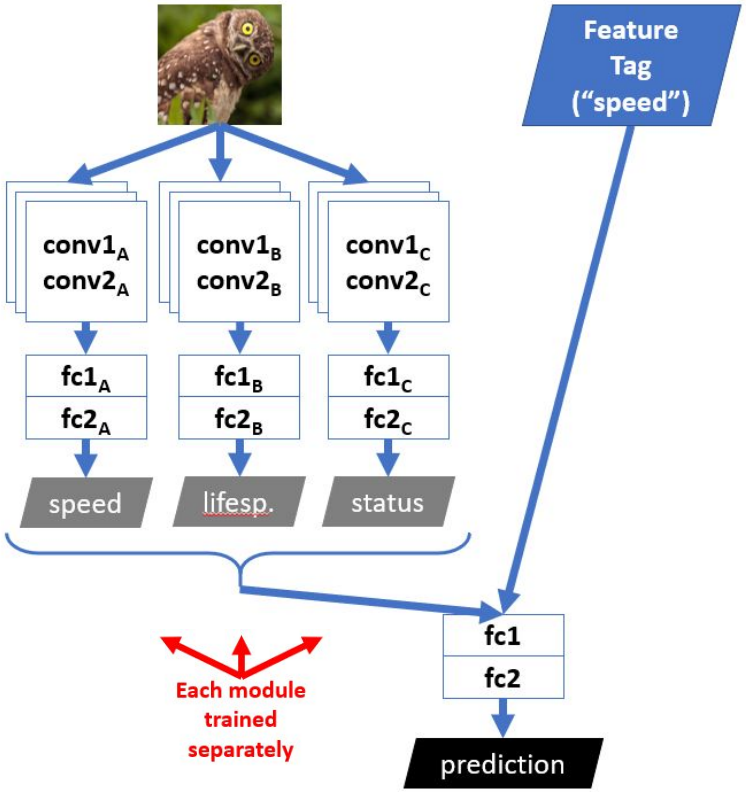
1. Train a **Distributed** NN and a **Feature-Specialized** NN to extract 3 features (speed, lifespan, conservation status) given animal images
2. Add a 4th feature, diet or social structure, to the training regimen, and continue training
3. Compare performance

Models

Distributed



Feature-Specialized



Results: Distributed Network

Average Speed (km/h)
Predicted: 19.63 - True Label: 9.00

Height (cm)
Predicted: 116.03 - True Label: 160.00

Weight (kg)
Predicted: 967.38 - True Label: 56.00

Average Speed (km/h)
Predicted: 19.63 - True Label: 60.00

Height (cm)
Predicted: 116.03 - True Label: 10.25

Weight (kg)
Predicted: 967.38 - True Label: 11.00

Converges to Constant :(

Results: Specialized Network

ALMOST Converges to Constant :(

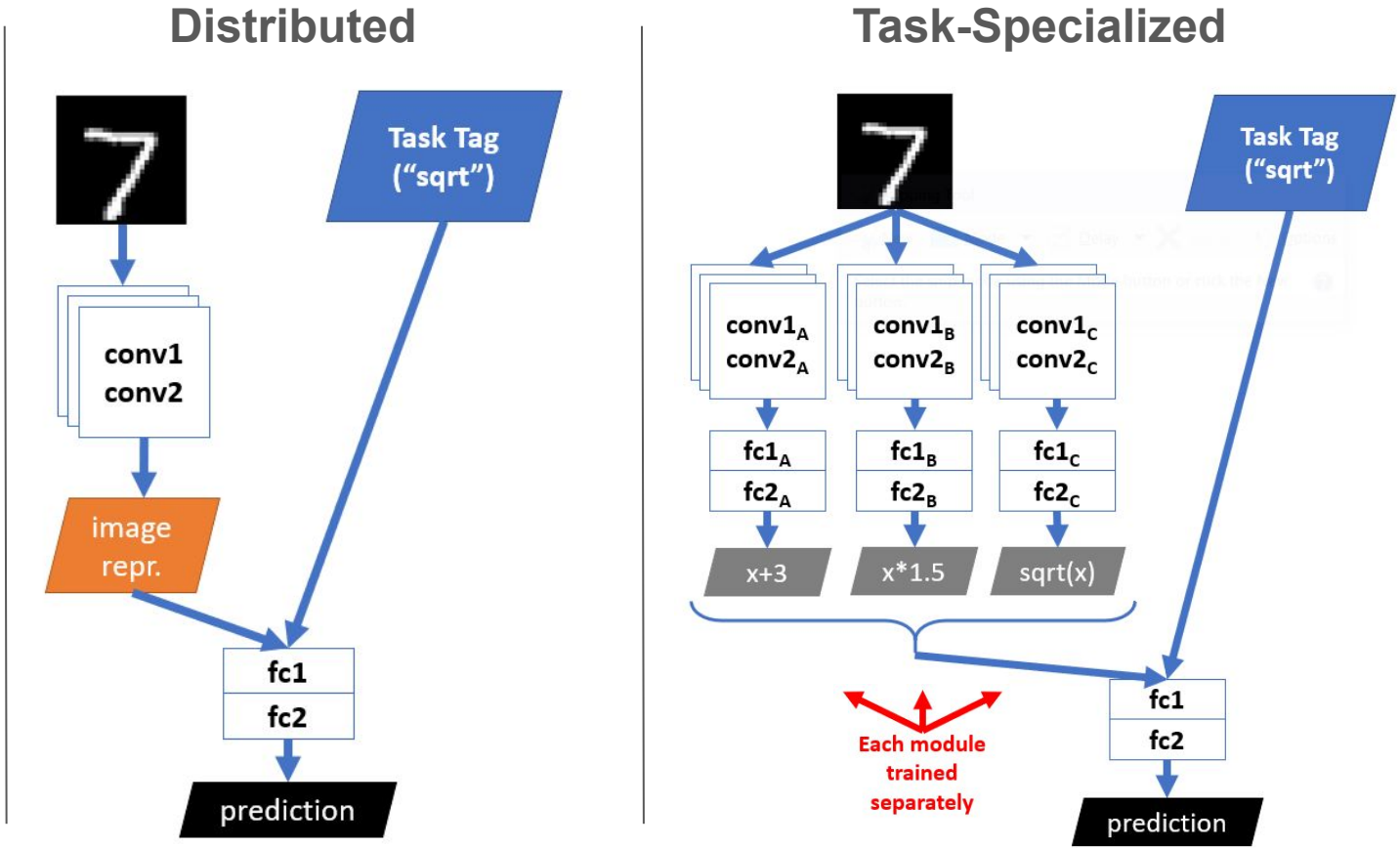
Trying MNIST

Train on:

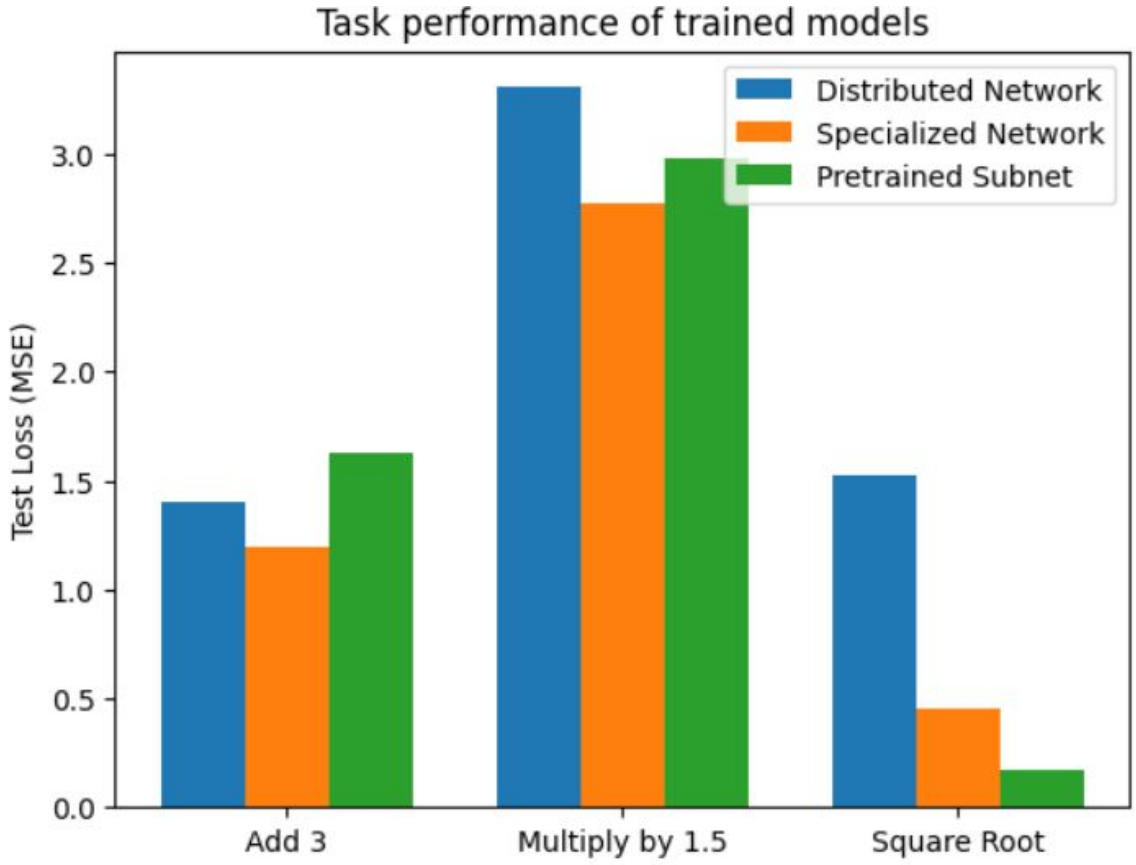
- x+3
- x*1.5
- sqrt(x)

4th task:

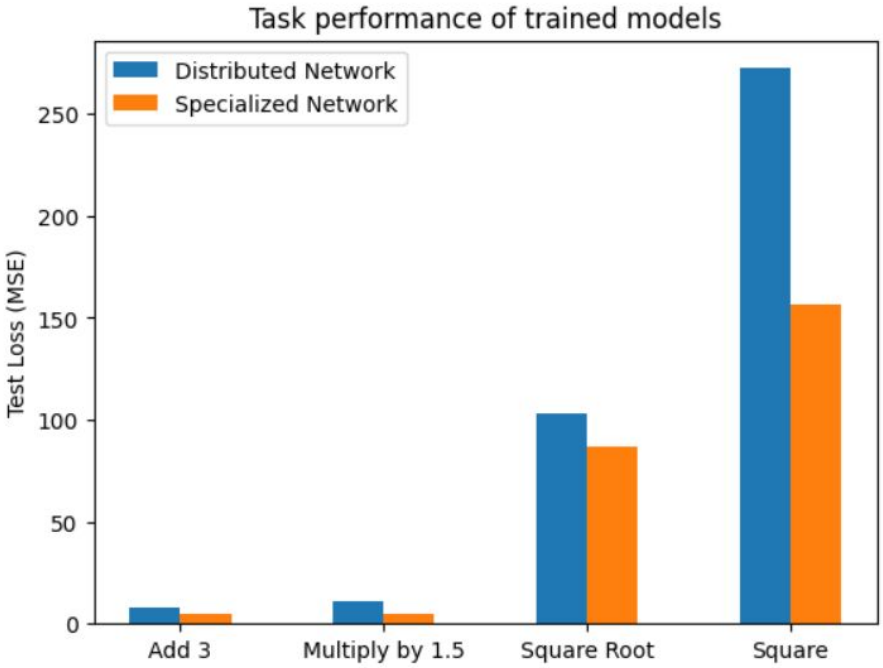
- x^2
- 2.3*sqrt(x)-1.4

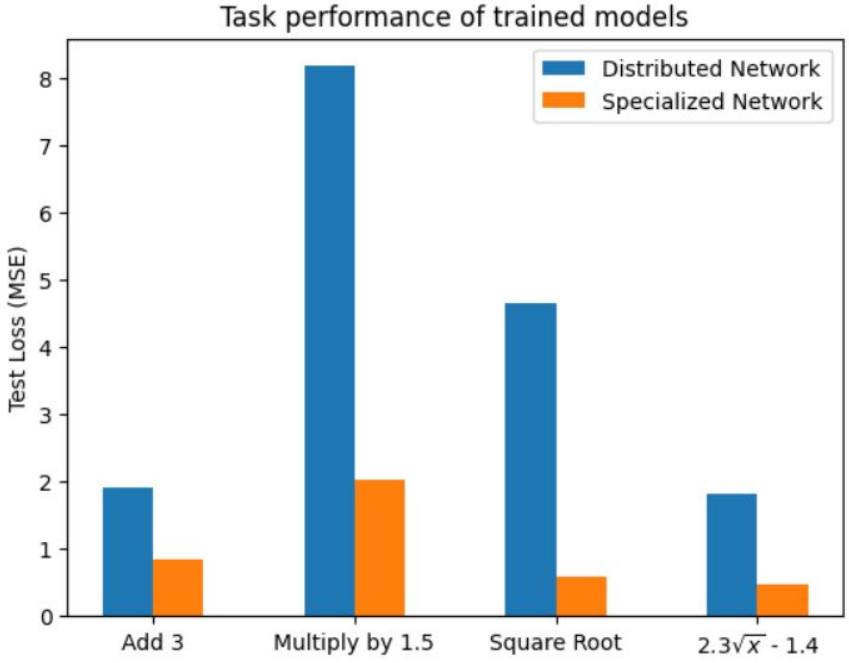


Training results on 3 initial tasks

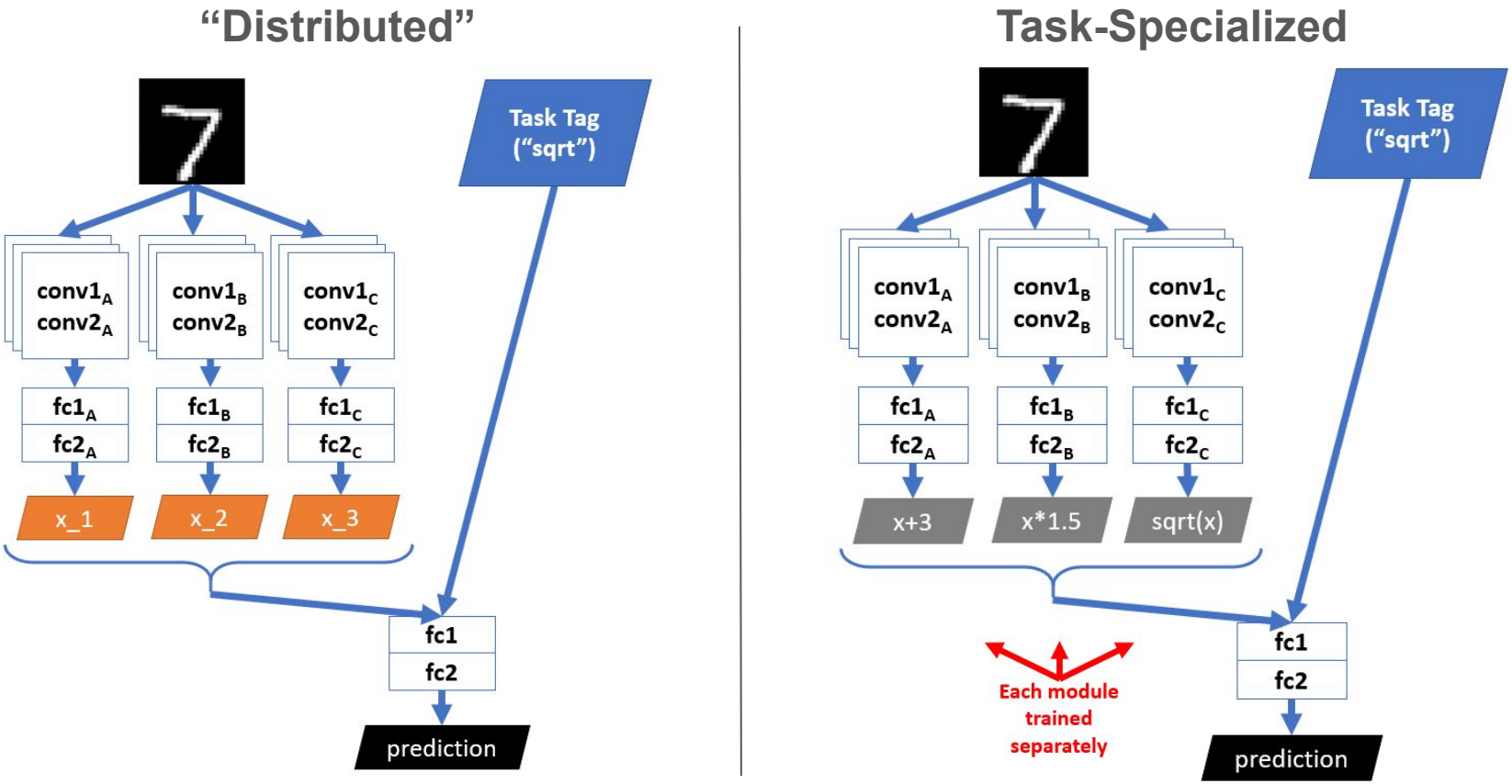


Adding 4th task and continuing training

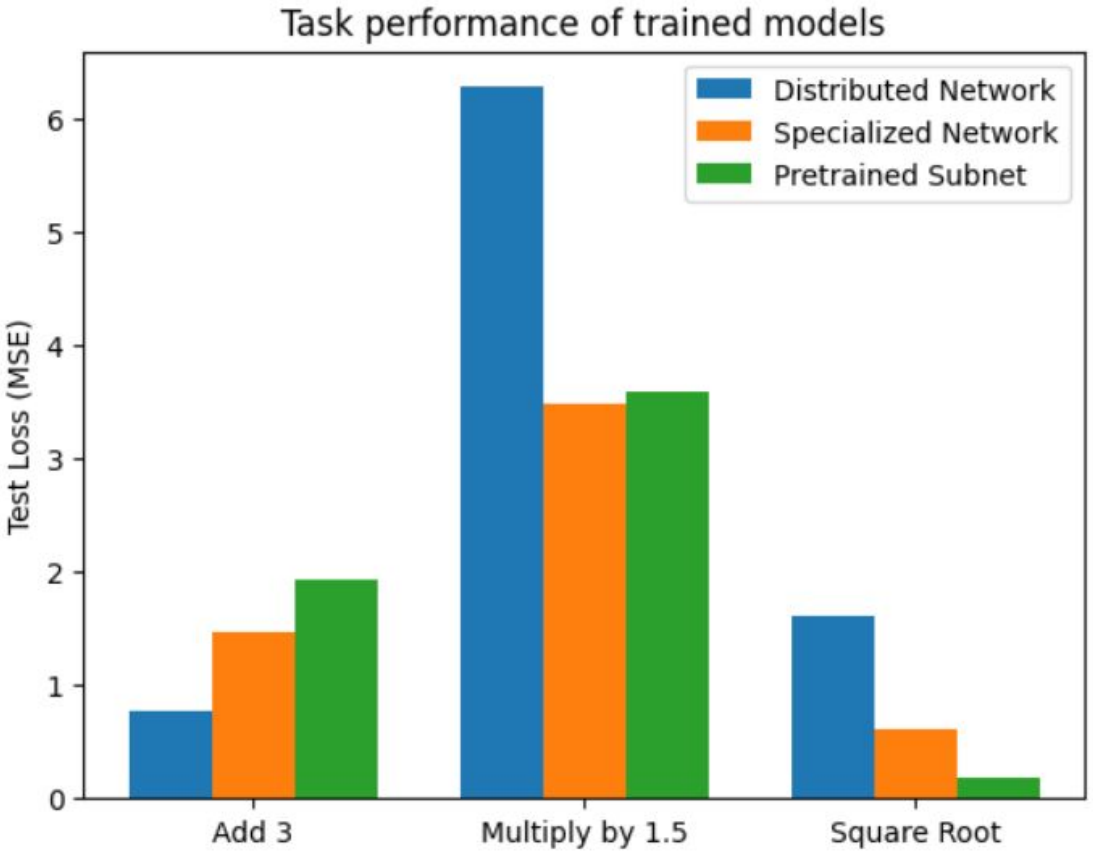




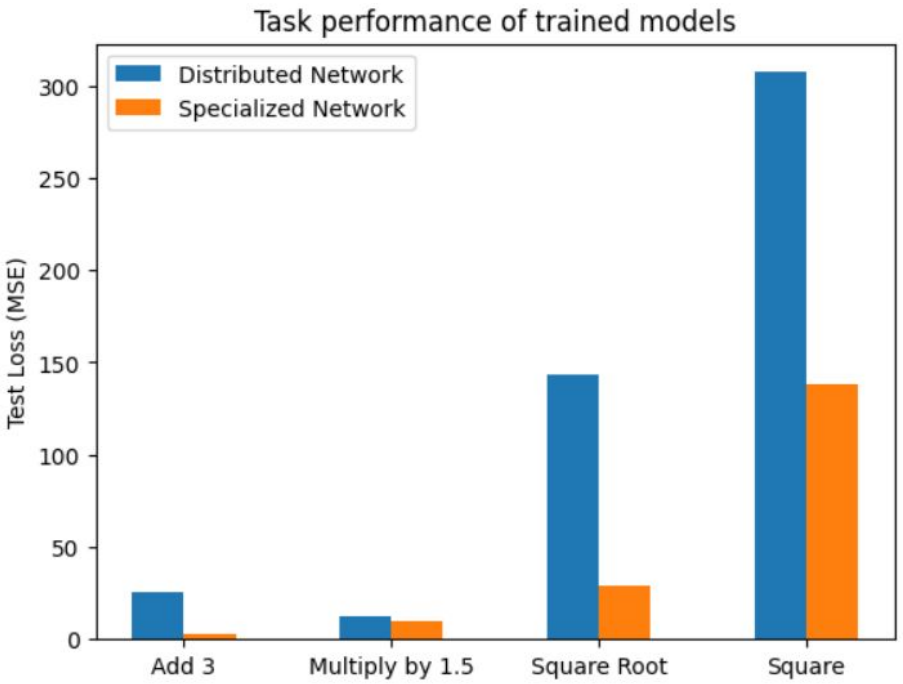
Controlling for architecture

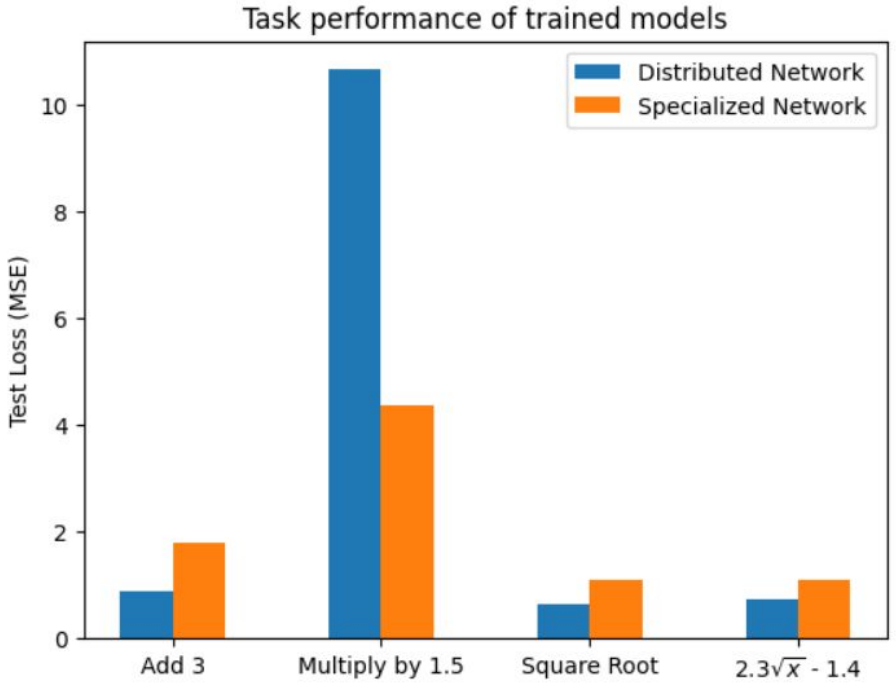


Same architecture: results on 3 initial tasks



Same architecture: adding 4th task and continuing training





Views and Principles

- Investigating the benefits of **distributed computation** in the context of **learning** a new **prediction** task
- Bridging the gap between two very different **representations** of the same concept

Future Directions

- Explore variations on model architecture, datasets, and features
- Experiment with different training strategies
- Better capture human intuition on feature learning
- Further control for model size and/or complexity
- What if the models must learn several new features/tasks at once?
- Look into learning dynamics to figure out why we see what we see