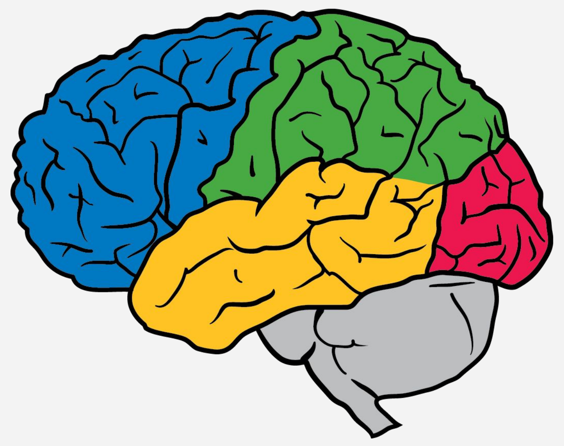

Learning Hierarchical Information Flow with Recurrent Neural Modules

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[1] Google Brain, [2] DeepMind

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1. Contribution

Learn connectivity rather than manually defining the layer structure for the task.

Brain-inspired sequence model consisting of communicating RNN modules.

Discovers skip-connections, feedback loops, and novel connectivity patterns.

Explored dynamic and static reading mechanisms.

Our model generalizes better and outperforms stacked GRUs on 3 sequential tasks.

2. Motivation

Neocortex often described as hierarchy but there are many side-connections and feedback loops:

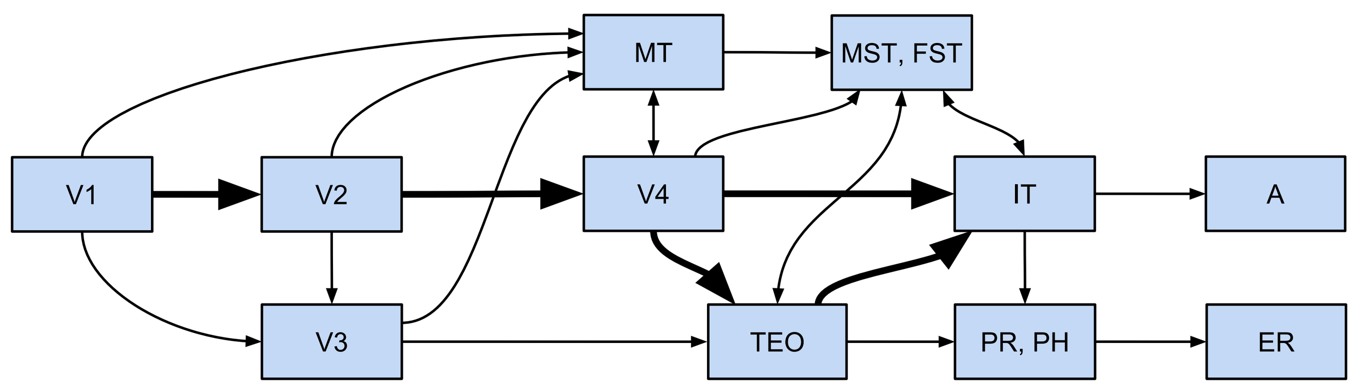


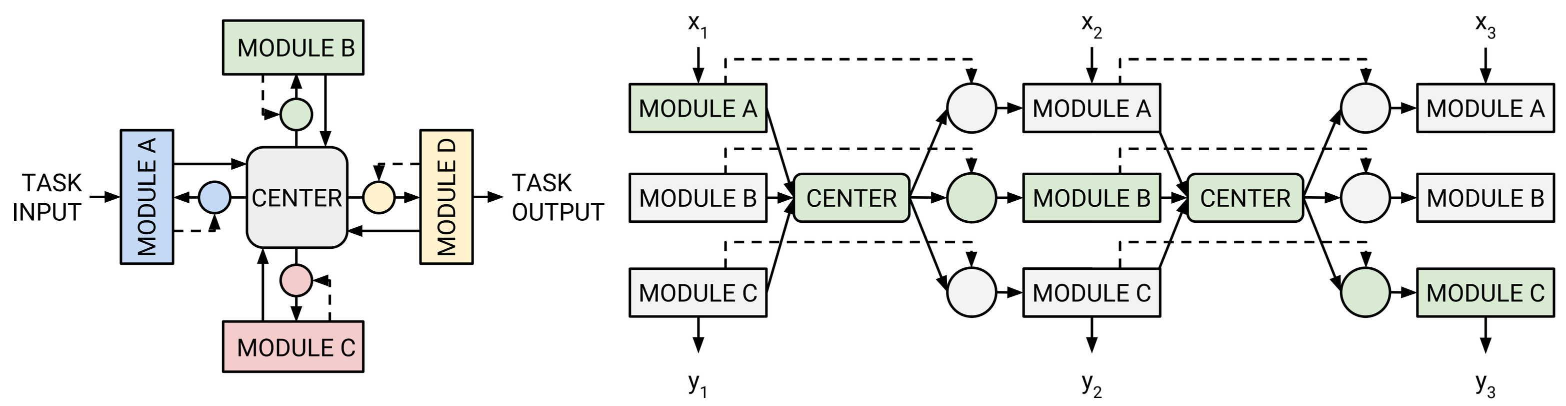
Figure adapted from: Gross et al. 1993. Inferior temporal cortex as a pattern recognition device.

Areas communicate both directly and indirectly via the thalamus. We focus on the latter here.

Modules communicating via a routing center include hierarchy as a special case.

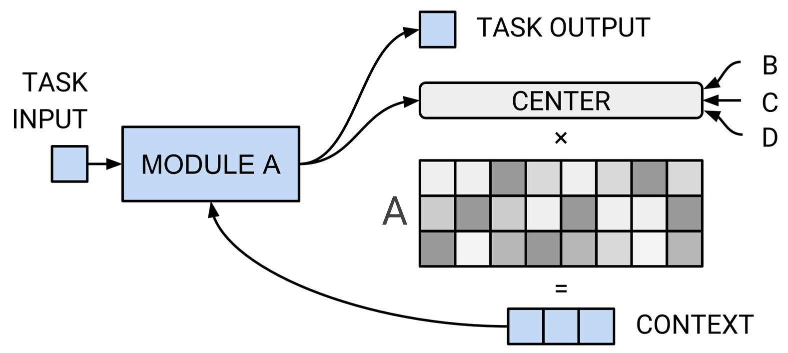
3. Method: ThalNet

Multiple recurrent modules share their features via a routing center center (concatenation of features):



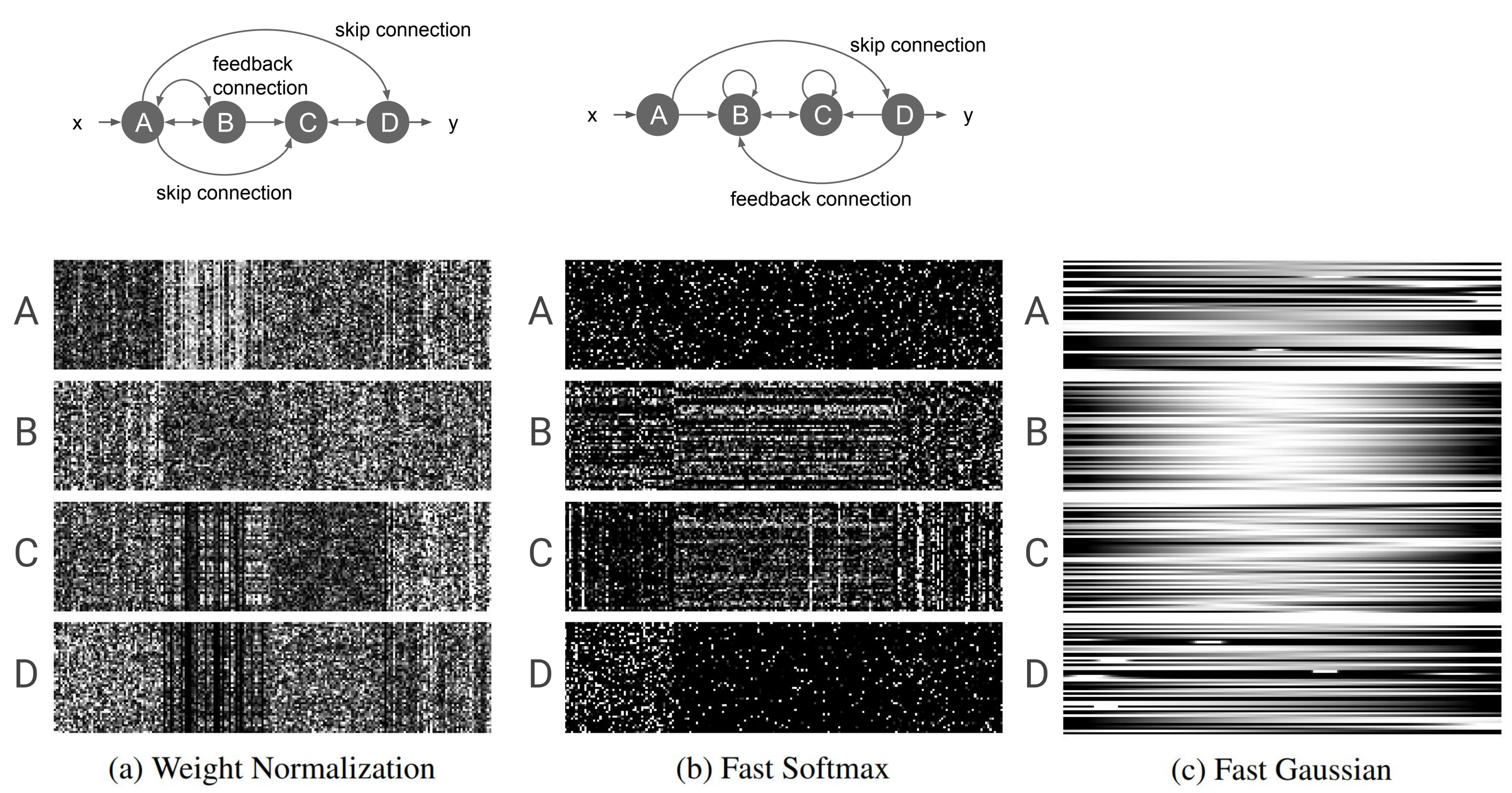
Possible information flow over time shown in green.

Modules observe the previous center value using dynamic or static reading mechanisms:



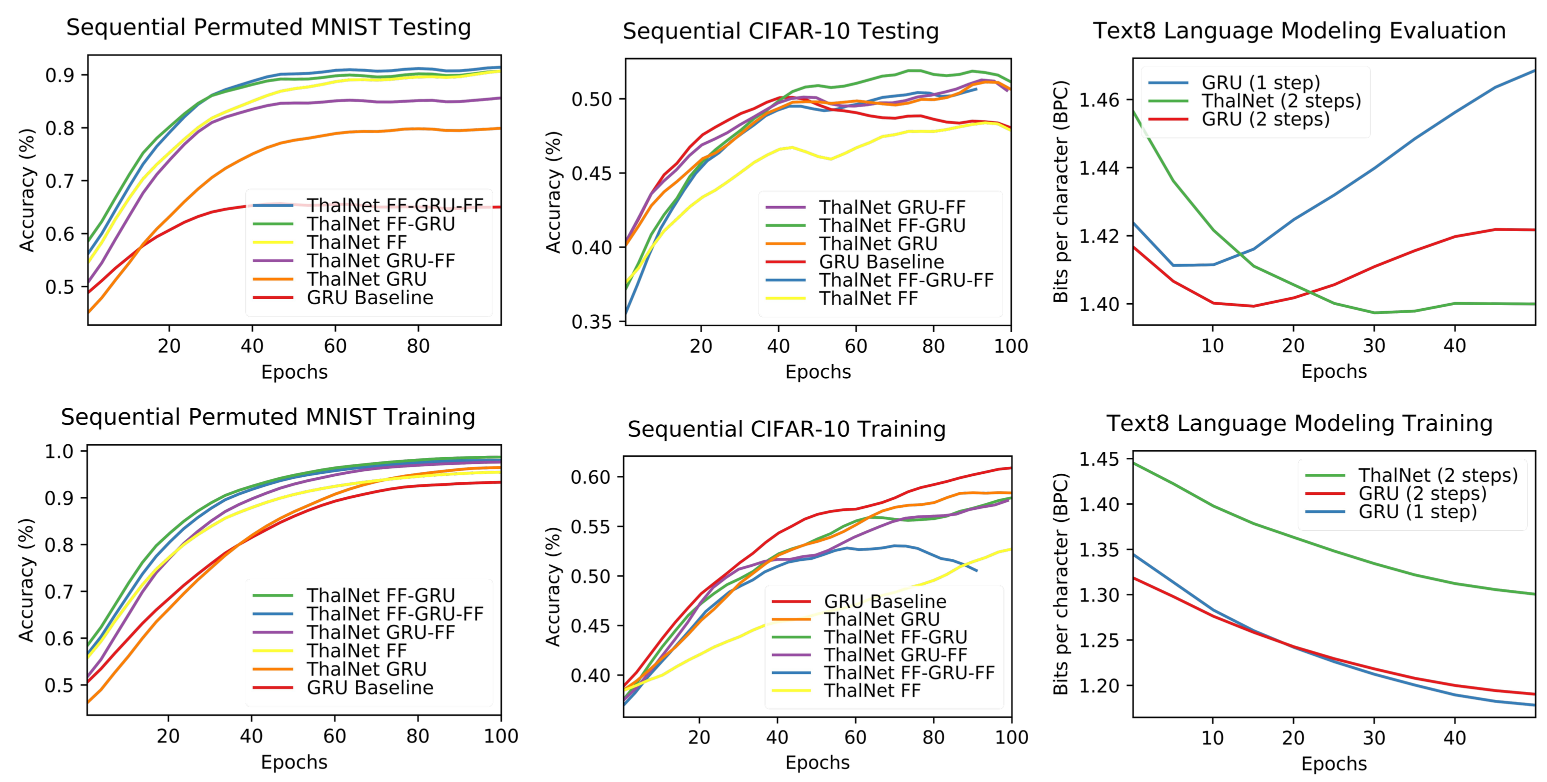
4. Findings

ThalNet learns hierarchical information flow, skip-connections, and long feedback pathways:



Learned reading weights for ThalNet with 4 modules and different reading mechanisms.

5. Performance



Task	GRU (params)	ThalNet (params)
Permuted MNIST	65% (50k)	**92%** (50k)
CIFAR-10	50% (50k)	**54%** (50k)
Text8	1.40 BPC (14M)	**1.40 BPC** (12M)

6. Conclusion

Similar connectivity is learned for the same task.

Modularity and reading bottleneck regularize the model and improve generalization.

The training time is about 2-3x that of the baseline.

Other recurrent models might benefit from long feedback loops learned by ThalNet.

Provides framework for multi-task learning and online architecture search.

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