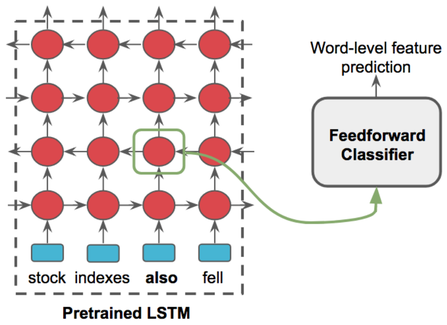
Deep RNNs Encode Soft Hierarchical Syntax

Terra Blevins, Omer Levy, and Luke Zettlemoyer

Paul G. Allen School of Computer Science & Engineering
University of Washington, Seattle, WA

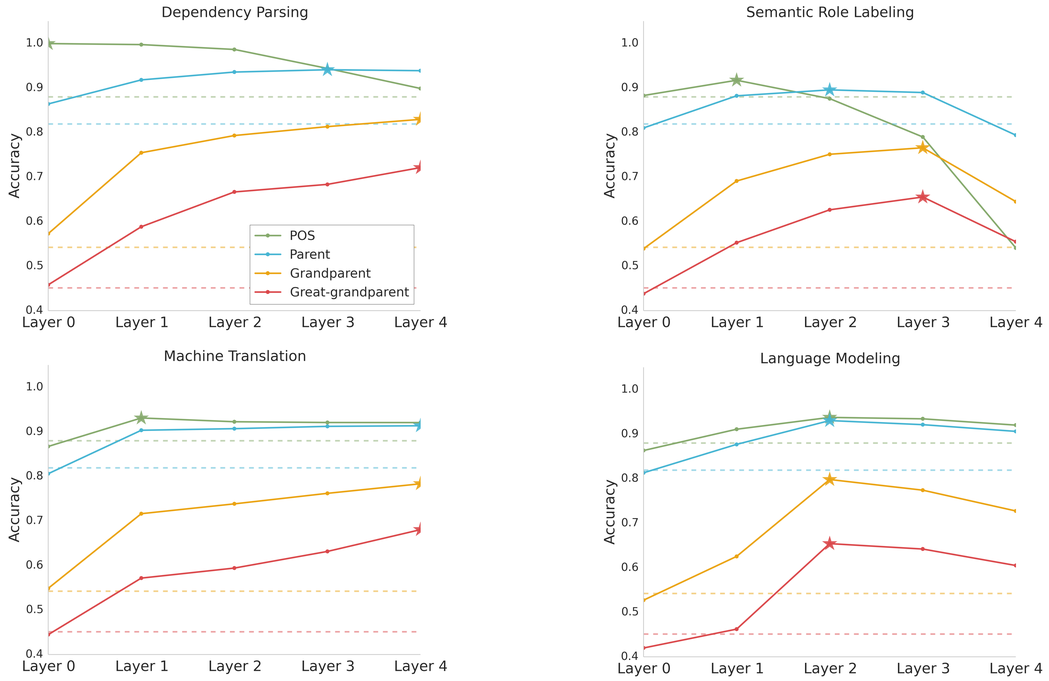
Deep RNNs can Learn Syntax

- **Method:** Predicting syntactic constituents from different layers of a recurrent neural network (RNN)
- **Experimental Variations**: RNNs pre-trained on different forms of supervision; predicting different levels of syntactic constituency
- **Results**: Networks encode soft notions of hierarchical syntax, with deeper layers encoding more about higher-level constituents



Methodology

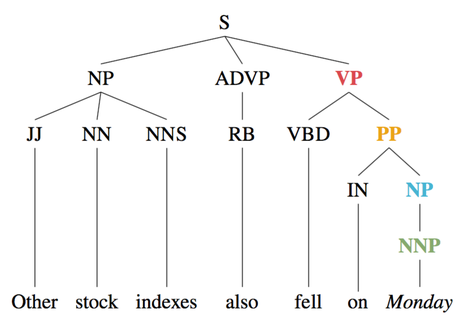
- Extract word-level representations from each hidden layer in pre-trained RNN
- Pre-trained models share same architecture: deep bidirectional LSTM network with four hidden layers
- Train a feedforward classifier to run syntactic auxiliary prediction tasks on these representations



Results of syntax experiments. The best performing layer for each experiment is annotated with a star, and the per-word majority baseline for each task is shown with a dashed line.

Experimental Setup

- **Forms of supervision**: dependency parsing, SRL, MT, and LM.
- **Prediction tasks**: POS tagging, and parent, grandparent, and great-grandparent constituent prediction
- **Baselines**: compare against a per-word majority baseline



Results

RNNs can induce syntax

- Models outperform baselines on every task.
- Indicates models encode syntax, even when not explicitly trained on syntax (i.e., SRL, MT, and LM)

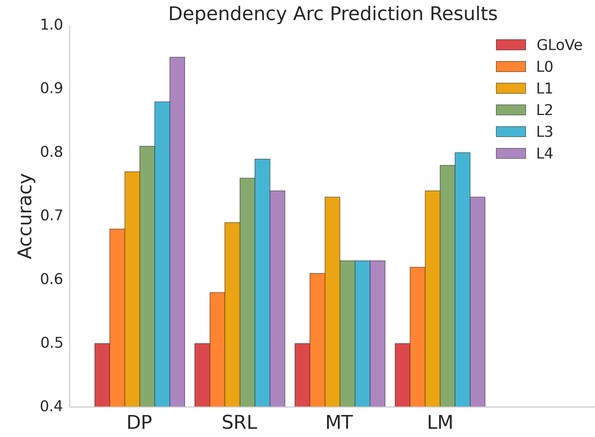
Deeper layers encode higher-level syntax: For most models, the more abstract syntax tasks peak on deeper layers than the shallower tasks.

Language models learn some syntax

- LM induces syntax despite "unsupervised" training signal
- Results on language modeling in line with previous work

Dependency Arc Prediction

- Predicting whether two words share an arc in the dependency tree over a sentence
- Same source models and setup as word level prediction tasks
- Given a word pair **c**, **p**, we input **[c; p; c∘p]** into the feedforward classifier



Conclusions

- The internal representations learned by deep NLP models induce syntax without explicit supervision.
- Results also suggest that these deep RNNs induce a soft hierarchy over the syntax they encode, using the different layers of the network.
- These results provide some insight as to why *deep* RNNs perform well on NLP tasks without annotated linguistic features.