Exploring numerical representations of language units

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Introduction

In a Nutshell

- What do I examine: Internal representation of Neural Networks Contextual word representation, mainly language models: BERT, GPT, XLM
- Aims of exploration: Examining learned linguistic features, improving transfer between tasks and languages.
- Examined Neural Networks: Mainly contextual representation of language models (BERT, GPT, XLM).

Methods of exploration

- Structural analysis: Answers the question: "Does particular components of the Neural Network know something about specific linguistic properties"?

- Behavioral analysis: Make inference of the models internal representation based on its behaviour in particular cases.

Topic Literature

- A survey of structural analysis: Belinkov and Glass 2019
- A survey of syntax representation in Neural Networks and Word Embeddings: Limisiewicz and Mareček 2020

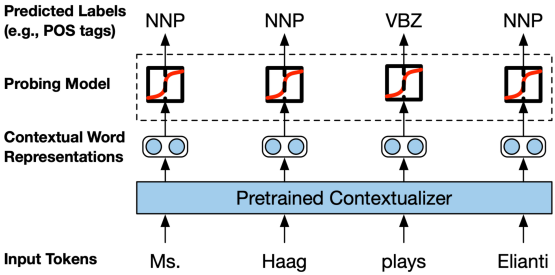
My Points of Focus

- Explanation of Neural Network representation
- Multilingual approaches, going beyond English
- Separation of task-specific information

Probing

Probing

- Contextual neural network models is trained, e.g. for Language Modeling, Translation
- The parameters of the network are fixed (frozen). A new simple network takes is trained on top for auxiliary linguistic task, e.g. POS tags prediction.
- We assume that when probing classifier accuracy is high the networks encodes linguistic abstraction well.



Liu et al. (2019): "Linguistic Knowledge and Transferability of Contextual Representations"

POS Probing Static vs. Contextual Representation

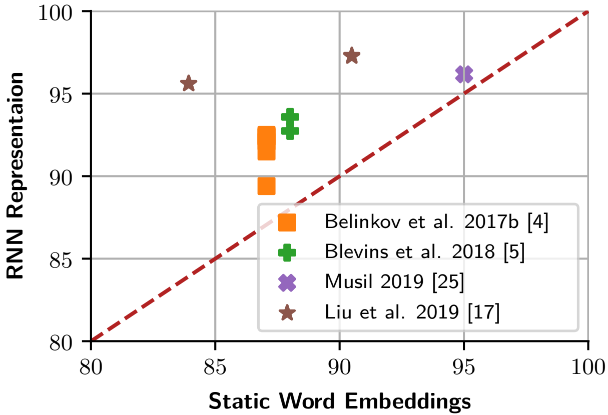


Figure 1: Accuracy of POS tag probing from RNN latent vectors compared with static word embeddings

POS Probing Influence of Pre-Training Task

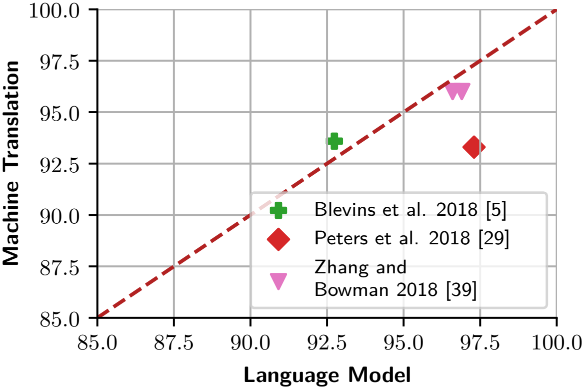


Figure 2: Accuracy of POS tag probing from RNN representation by the pre-training objective

Syntactic Structures

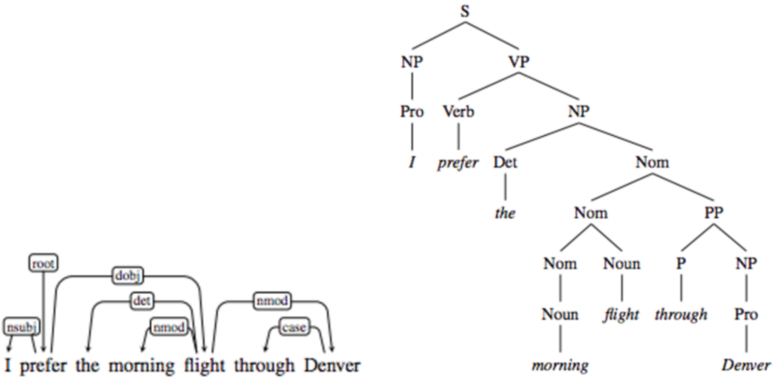


Figure 3: Comparison of two widely used syntactic structure types: dependency and constituency trees, from Jurafsky and Martin 2009

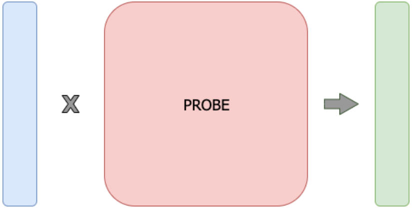
Syntactic Structure Probing

- Hewitt and Manning 2019 multiply contextual vectors by trainable matrix to approximate syntactic tree distance between tokens by the L2 norm of the difference of the transformed vectors.

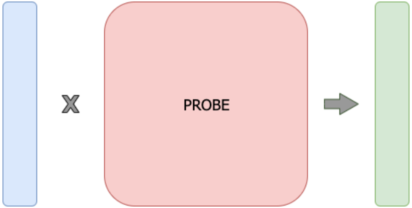
$$\min_B \left|(B(h_i - h_j))^T (B(h_i - h_j)) - d_T(w_i, w_j)\right| \tag{1}$$

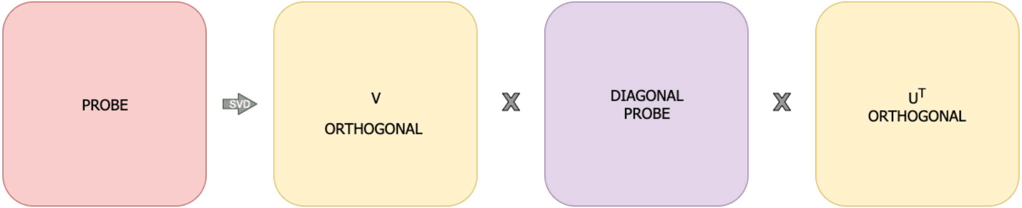
- This approach produces the approximate syntactic pairwise distances for each pair of tokens. The minimum spanning tree is used to create a dependency tree with high accuracy (82.5% UAS on Penn Treebank).

Orthogonal Probing

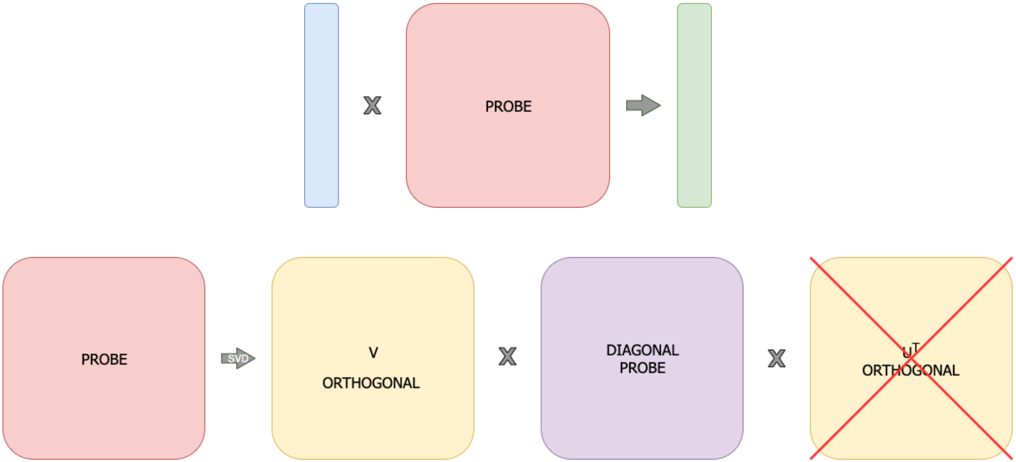


Orthogonal Probing

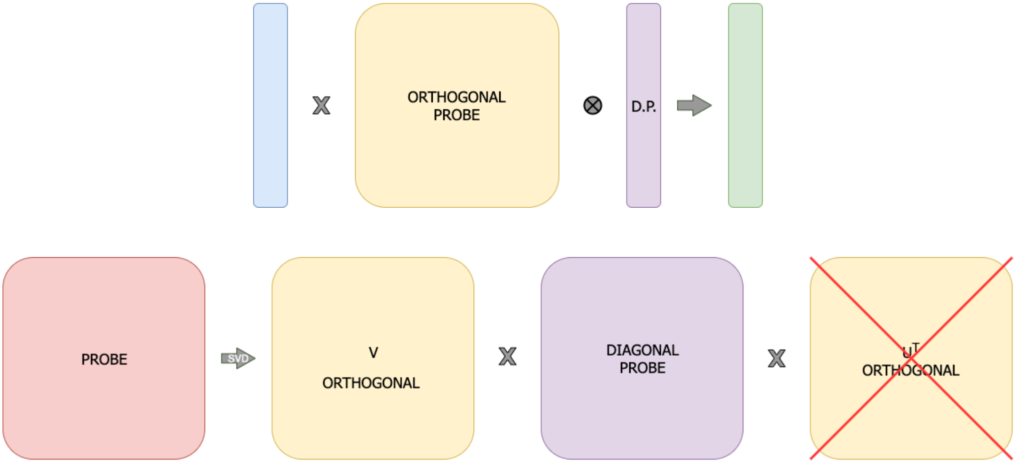




Orthogonal Probing



Orthogonal Probing



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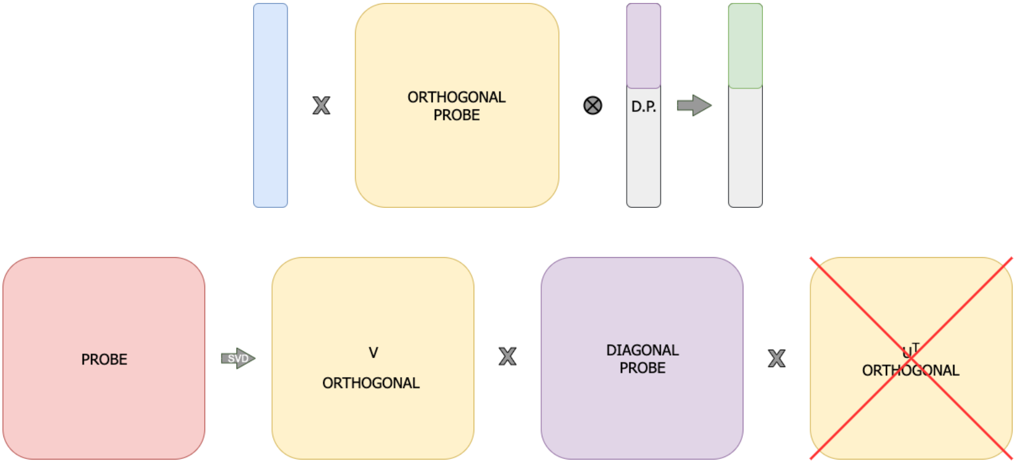


Disentangled Concise Representation

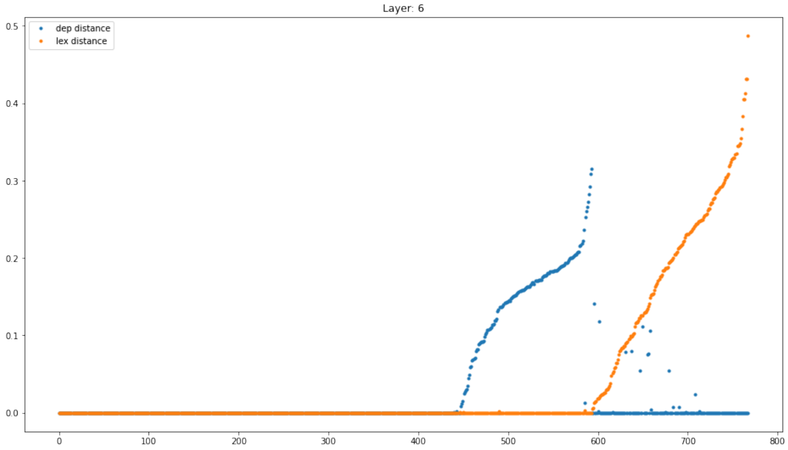


Figure 4: Lexical and syntactic information is separated by a syntactic probe

Advantages and Issues

+ Good results in induction of the Syntactic Trees
+ Clearly visible distinction between layer
+ Possibility to reduce number of dimension of the vector
– Strong supervision of the probe
– The structure can be memorized in the additional layer instead of being encoded in the representation

Attention matrices

Dependency Tree in Attention Matrices

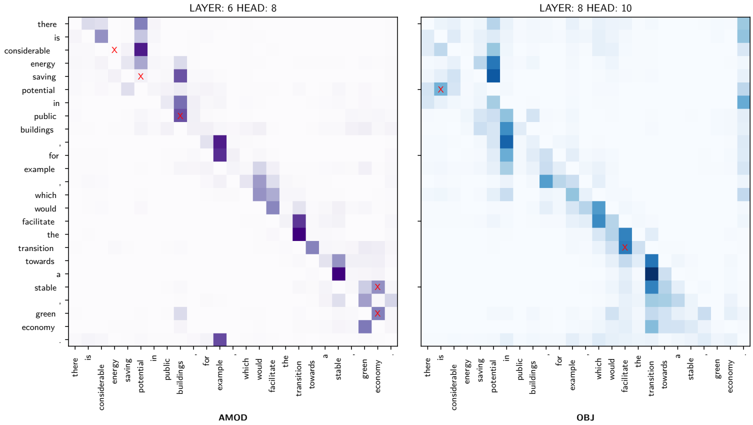


Figure 5: Self-attention in a particular heads of a language model aligns with dependency relations: adjective modifier, objectives

Advantages and Issues

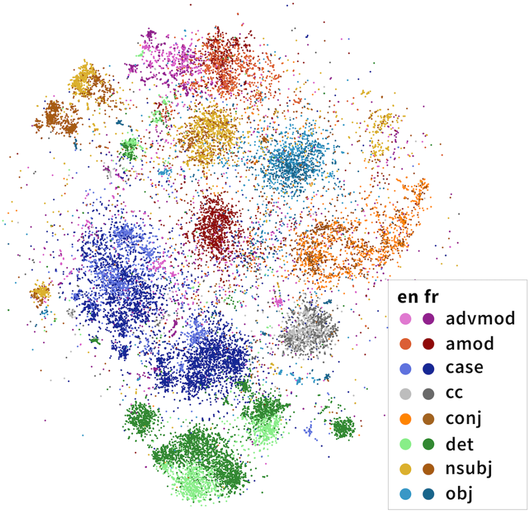
+ Less supervision needed, observations based on qualitative analysis
+ Is not restricted by annotation guidelines
– Some annotation is needed to automatically identify syntactic heads
– Generally gives worse results than structural probing

Challenges

Going multilingual

- Chi, Hewitt, and Manning 2020 probed multilingual model for syntactic structure. They evaluated transfer between languages
- Kulmizev et al. 2020 probed and compared two annotation styles (UD and SUD).
- Limisiewicz, Rosa, and Mareček 2020 we extracted syntactic trees from multilingual model.

All the approaches used multilingual BERT.



Multi-tasking

- Syntax
- Lexicology
- Discourse: coreferences
- Semmantics
- ...