Studying the Acquisition of WordNet Relations in Portuguese from Pretrained MLMs

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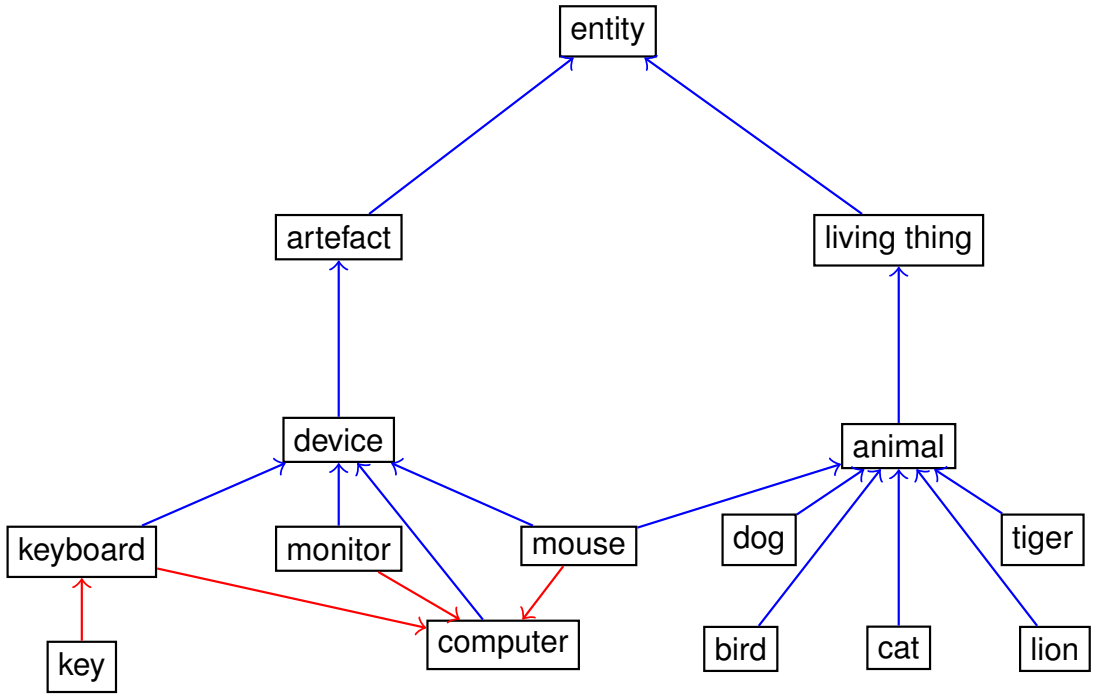
Motivation

- A **wordnet** can be seen as a graph...
  - **Nodes** = concepts, possibly denoted by words
  - **Edges** = (**explicit**) relations between nodes



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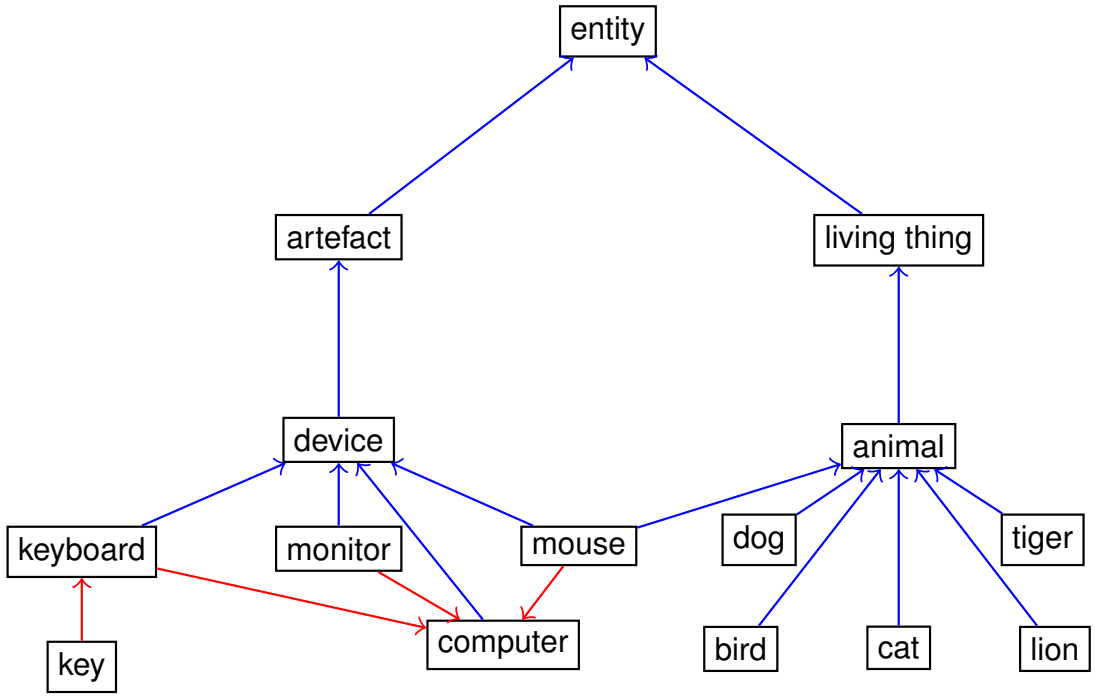

- In many cases, creation is **manual**!

Relation Acquisition from Corpora

- In order to automatise / accelerate the creation of wordnets...

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Hearst (1992) patterns

NP , NP* , (and|or) other NP_H
NP_H such as , NP* , (or|and) NP
such NP_H as , NP* , (or|and) NP
NP_H , including NP,* (or|and) NP
NP_H , especially NP,* (or|and) NP

$\Rightarrow$ hyponymOf(NP, NP_H)

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* *... works by such authors as Herrick, Goldsmith, and Shakespeare.*

* *... Bruises, wounds, broken bones or other injuries ...*

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$\rightarrow$ hyponym(Herrick, author), hyponym(Goldsmith, author), hyponym(Shakespeare, author)

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Learn more patterns automatically

- Using WordNet relations as seeds...
  - distant supervision (Snow et al., 2005)
  - weak supervision (Pantel and Pennacchiotti, 2006)

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bird

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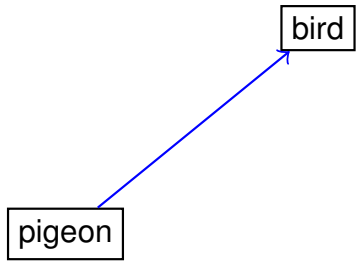
    - pigeon (0.177)



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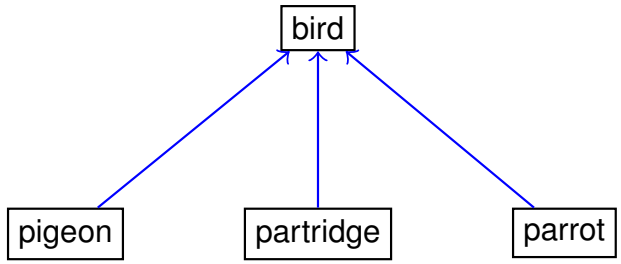
  - `A [MASK] is a type of bird.`
    - pigeon (0.177)
    - parrot (0.048)
    - partridge (0.043)
    - raven (0.037)
    - heron (0.035)



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1. Compile a set of lexical patterns for WordNet relations.
   - One fixed argument (X_1), to be replaced before prediction
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   * e.g., for hypernymy: X_1 `is a type of [MASK].`

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   - Explore the relation-validation service VARRA (Freitas et al., 2015)

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   - B^2SG: TOEFL-like test
   - TALES: test of lexico-semantic analogies

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   - B^2SG: TOEFL-like test
   - TALES: test of lexico-semantic analogies
4. Compare with performance of alternative methods

Prompting BERT MLM

- Manually-compiled patterns that indicate target relations in Portuguese text (Gonçalo Oliveira, 2022)
  - Synonym-of
  - Antonym-of
  - Hypernym-of, Hyponymy-of

Prompting BERT MLM

- Manually-compiled patterns that indicate target relations in Portuguese text (Gonçalo Oliveira, 2022)
  - Synonym-of
  - Antonym-of
  - Hypernym-of, Hyponymy-of
- Additional patterns adapted from VARRA (Freitas et al., 2015), a service for validating Portuguese semantic relations in corpora
  - regex $\rightarrow$ masked prompt

Relation	VARRA	Masked Prompt
Synonym-of	`[lema="PALAVRA1"] "," "isto" "é" "," [lema="PALAVRA2"]`	X_1 `, isto é, [MASK]`

Antonym-of	`[word="nem|seja|quer"] [lema="PALAVRA1"] [lema=","]* [word="nem|seja|quer"] [lema="PALAVRA2"]`	`nem` X_1 `, nem [MASK]`
		`seja` X_1 `, seja [MASK]`
		`quer` X_1 `, quer [MASK]`

Hypernym-of	`[lema="PALAVRA1"] [pos="ADJ.*"]* [lema=","]* [lema="tal"]* "como" [pos="DET.*"]* [pos="ADJ.*"]* [lema="PALAVRA2"]`	X_1 `, tal como [MASK]`
Hypernym-of	`[lema="PALAVRA2" & pos="N.*"] "e" [lema="outro"] [lema="PALAVRA1" & pos="N.*"]`	X_1 `e outro [MASK]`

B²SG[1] (Wilkens et al., 2016)

- TOEFL-like test for Portuguese
  - **Multiple-choice**: four options, only one word related to the source
  - Based on the Portuguese part of BabelNet

[1] http://www.inf.ufrgs.br/pln/resource/B2SG.zip

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- TOEFL-like test for Portuguese
  - **Multiple-choice**: four options, only one word related to the source
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  - Similar to the WordNet-Based Synonymy Test, covering 6 relations
    - Synonyms, Antonyms, Hypernyms, each between nouns and between verbs

Synonyms (v)				
`trancar` (lock	`barrar` block	`aviar` serve	`alienar` alienate	`progredir` progress)
`estremecer` (shudder	`tremer` tremble	`avermelhar` redden	`esconder` hide	`suspirar` sigh)
Antonyms (n)				
`esquerda` (left	`direita` right	`repressão` repression	`sétimo` seventh	`diácono` deacon)
`perfeição` (perfection	`defeito` defect	`junção` junction	`mutilação` mutilation	`prémio` premium)
Hyponyms (n)				
`matemática` (mathematics	`ciência` science	`célula` cell	`pulseira` bracelet	`libertação` release)
`chapéu` (hat	`sombreiro` sombrero	`cavalaria` cavalry	`gavião` hawk	`dissidente` dissident)

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* **Accuracy:** proportion of source words for which the correctly related target is selected

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TALES[2] (Gonçalo Oliveira et al., 2020)

- Analogy-like test of Portuguese lexico-semantic relations
  - Contents acquired from open Portuguese LKBs
  - 50 entries for each of 14 relation types, including:
    - Synonymy (nouns, verbs, adjectives), Antonymy (adjectives)
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  - Same format as BATS (Drozd et al. (2016))...

Synonym-of (n)	
`proprietário` (owner)	`dono/senhor/titular/amo` (lord/holder/master)
`sabor` (flavour)	`gosto/paladar` (taste/palate)
Antonym-of (adj)	
`novo` (young)	`velho/idoso/entradote` (old/aged/oldish)
`certo` (certain/right)	`incerto/incorreto` (uncertain/incorrect)
Hypernym-of (concrete)	
`casa` (house)	`vila/residência/cabana/estalagem/...` (vila/residence/hut/inn/...)
`livro` (book)	`volume/álbum/catecismo/missal/...` (volume/album/catechism/prayer book/...)

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* **Accuracy:** proportion of source words for which the top prediction is a target word

* **Accuracy@10:** proportion of source words for which a target word is in the top-10 predictions

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Models

- Experiments focused on three pretrained BERT models, all available from the Huggingface Hub:
  - BERTimbau (Souza et al., 2020), BERT pretrained for Portuguese
    - BERTimbau-base[3] (BERT-base), 12 layers, 110M parameters;
    - BERTimbau-large[4] (BERT-base), 24 layers, 335M parameters.
  - Multilingual BERT[5] (BERT-ML), pretrained on Wikipedia for 104 languages, 12 layers, 110M parameters.

[3] neuralmind/bert-base-portuguese-cased
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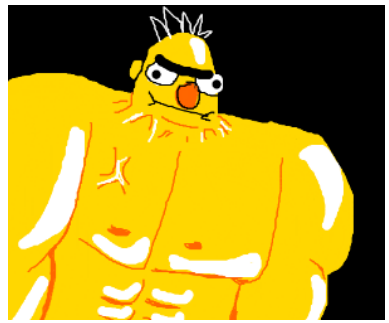
  - Multilingual BERT[5] (BERT-ML), pretrained on Wikipedia for 104 languages, 12 layers, 110M parameters.
- For each entry of the dataset + masked pattern for its relation...
  - B^{2}SG: FitBERT[6] instantiated with each model used for selecting the most suitable option.
  - TALES: `fill-mask` pipeline in each model, for predicting suitable tokens for the mask.



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Results in B^{2}SG

Accuracy

Relation	PoS	Pattern		BERT-ML	BERT-base	BERT-large
Synonym-of	N	X_1 é o mesmo que [MASK] (X_1 is the same as [MASK])		0.35	0.57	**0.64**
Synonym-of	N	X_1, isto é, [MASK] (X_1, this is, [MASK])	*V*	0.33	0.58	0.62
Synonym-of	V	X_1, isto é, [MASK] (X_1, this is, [MASK])	*V*	0.32	0.50	**0.56**
Synonym-of	V	X_1, ou seja, [MASK] (X_1, i.e., [MASK])	*V*	0.49	0.54	0.37
Antonym-of	N	nem [MASK], nem X_1 (not X_1, nor [MASK])	*V*	0.44	0.76	**0.77**
Antonym-of	N	X_1 é o contrário de [MASK] (X_1 is the opposite of [MASK])		0.46	0.72	0.77
Antonym-of	V	se está a X_1 não está a [MASK] (if it is X_1, it is not [MASK])		0.46	0.60	0.62
Antonym-of	V	nem [MASK], nem X_1 (not X_1, nor [MASK])	*V*	0.29	**0.63**	0.61
Hypernym-of	N	X_1, isto é, um tipo de [MASK] (X_1, this is, a type of [MASK])	*V*	0.44	0.68	**0.71**
Hypernym-of	N	X_1, isto é, uma espécie de [MASK] (X_1, this is, a kind of [MASK])	*V*	0.41	0.63	0.70
Hypernym-of	V	a X_1 ou outras formas de [MASK] (X_1 or other forms of [MASK])	*V*	0.36	0.61	**0.66**
Hypernym-of	V	a X_1 ou outros modos de [MASK] (X_1 or other modes of [MASK])		0.37	0.57	0.61

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* Always higher than the random chance (25%)
  - Variable performance depending on relation, pattern, model, ...
  - BERTimbau-large generally the best option

Results in B²SG

Other methods

- Other BERT-based approaches: most similar according to...
  - `[CLS]` embeddings
  - Mean pooling of token embeddings
  - BERTimbau fine-tuned for Semantic Textual Similarity

Relation	PoS	BERT-b (patterns)	BERT-l (patterns)	BERT-b (CLS)	BERT-l (CLS)	BERT-b (tokens)	BERT-l (tokens)	BERT-STS
Synonym-of	N	0.58	0.64	0.60	0.67	0.59	0.66	0.80
Synonym-of	V	0.54	0.56	0.55	0.51	0.54	0.54	**0.75**
Antonym-of	N	0.76	0.77	0.72	0.63	0.69	0.64	0.78
Antonym-of	V	0.63	0.62	0.51	0.51	0.49	0.57	0.68
Hypernym-of	N	0.68	0.71	0.59	0.61	0.59	0.62	0.76
Hypernym-of	V	0.61	0.66	0.52	0.51	0.54	0.54	**0.71**

Results in B^{2}SG

Other methods

- Other BERT-based approaches: most similar according to...
  - `[CLS]` embeddings
  - Mean pooling of token embeddings
  - BERTimbau fine-tuned for Semantic Textual Similarity

Relation	PoS	BERT-b (patterns)	BERT-l (patterns)	BERT-b (CLS)	BERT-l (CLS)	BERT-b (tokens)	BERT-l (tokens)	BERT-STS
Synonym-of	N	0.58	0.64	0.60	0.67	0.59	0.66	0.80
Synonym-of	V	0.54	0.56	0.55	0.51	0.54	0.54	**0.75**
Antonym-of	N	0.76	0.77	0.72	0.63	0.69	0.64	0.78
Antonym-of	V	0.63	0.62	0.51	0.51	0.49	0.57	0.68
Hypernym-of	N	0.68	0.71	0.59	0.61	0.59	0.62	0.76
Hypernym-of	V	0.61	0.66	0.52	0.51	0.54	0.54	**0.71**

- Most similar according to...
  - 300-sized word embeddings, pretrained for Portuguese (Hartmann et al., 2017)

Relation	PoS	CBOW	Skip	GloVe
Synonym-of	N	0.71	**0.83**	0.81
Synonym-of	V	0.66	0.68	0.70
Antonym-of	N	0.70	0.81	**0.83**
Antonym-of	V	0.67	0.69	**0.71**
Hypernym-of	N	0.65	0.76	**0.80**
Hypernym-of	V	0.64	0.66	0.70

Results in TALES

Accuracy of best patterns

Relation	PoS	Pattern		BERT-ML	BERT-base	BERT-large
Synonym-of	N	X_1 é sinónimo de [MASK] (X_1 is a synonym of [MASK])		0.02	**0.28**	0.20
Synonym-of	V	X_1 é o mesmo que [MASK] (X_1 is the same as[MASK])		0.12	0.12	**0.34**
Synonym-of	ADJ	estar X_1 é o mesmo que estar [MASK]. (being X_1 is the same as being [MASK])		0.14	0.06	**0.24**
Antonym-of	ADJ	ser [MASK] é o contrário de ser X_1 (being X_1 is the opposite of being [MASK])		0.08	0.26	**0.38**
Hypernym-of	Abstract	a [MASK] é um tipo de X_1 (the [MASK] is a type of X_1)		0.08	0.22	**0.38**
Hypernym-of	Concrete	o [MASK], que é um tipo de X_1 (the [MASK], which is a type of X_1)	*V*	0.08	0.20	**0.24**
Hypernym-of	V	como [MASK] e outros modos de X_1 (like [MASK] and other modes of X_1)		0.00	0.08	**0.20**
Hyponym-of	Abstract	um X_1, isto é, um tipo de [MASK] (a X_1, this is, a type of [MASK])	*V*	0.02	0.24	**0.40**
Hyponym-of	Concrete	uma X_1, isto é, um tipo de [MASK] (a X_1, this is, a type of [MASK])	*V*	0.10	**0.60**	0.56
Hyponym-of	V	como X_1 ou outras maneiras de [MASK] (like X_1 and other manners of [MASK])		0.18	**0.24**	0.18

Results in TALES

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Relation	PoS	Pattern		BERT-ML	BERT-base	BERT-large
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Synonym-of	V	X_1 é o mesmo que [MASK] (X_1 is the same as[MASK])		0.12	0.12	**0.34**
Synonym-of	ADJ	estar X_1 é o mesmo que estar [MASK]. (being X_1 is the same as being [MASK])		0.14	0.06	**0.24**
Antonym-of	ADJ	ser [MASK] é o contrário de ser X_1 (being X_1 is the opposite of being [MASK])		0.08	0.26	**0.38**
Hypernym-of	Abstract	a [MASK] é um tipo de X_1 (the [MASK] is a type of X_1)		0.08	0.22	**0.38**
Hypernym-of	Concrete	o [MASK], que é um tipo de X_1 (the [MASK], which is a type of X_1)	*V*	0.08	0.20	**0.24**
Hypernym-of	V	como [MASK] e outros modos de X_1 (like [MASK] and other modes of X_1)		0.00	0.08	**0.20**
Hyponym-of	Abstract	um X_1, isto é, um tipo de [MASK] (a X_1, this is, a type of [MASK])	*V*	0.02	0.24	**0.40**
Hyponym-of	Concrete	uma X_1, isto é, um tipo de [MASK] (a X_1, this is, a type of [MASK])	*V*	0.10	**0.60**	0.56
Hyponym-of	V	como X_1 ou outras maneiras de [MASK] (like X_1 and other manners of [MASK])		0.18	**0.24**	0.18

* Not constrained by the options → much more challenging!

- BERT-large still the best choice

Results in TALES

Accuracy@10

Relation	PoS	Pattern		BERT-ML	BERT-base	BERT-large
Synonym-of	N	X_1 é sinónimo de [MASK] (X_1 is a synonym of [MASK])		0.20	0.64	**0.70**
Synonym-of	V	X_1 é o mesmo que [MASK] (X_1 is the same as[MASK])		0.24	0.80	**0.90**
Synonym-of	ADJ	ser X_1 é o mesmo que ser [MASK]. (being X_1 is the same as being [MASK])		0.24	0.54	**0.64**
Antonym-of	ADJ	ser [MASK] é o contrário de ser X_1 (being X_1 is the opposite of being [MASK])		0.22	0.40	**0.48**
Hypernym-of	Abstract	uma [MASK], isto é, um tipo de X_1 (a [MASK], this is, a type of X_1)	*V*	0.32	**0.70**	0.62
Hypernym-of	Concrete	o [MASK], que é um tipo de X_1 (the [MASK], which is a type of X_1)	*V*	0.20	0.54	**0.56**
Hypernym-of	V	como [MASK] e outros modos de X_1 (like [MASK] and other modes of X_1)		0.04	0.54	**0.58**
Hyponym-of	Abstract	uma X_1, isto é, uma espécie de [MASK] (a X_1, this is, a kind of [MASK])	*V*	0.38	**0.66**	0.64
Hyponym-of	Concrete	uma X_1, isto é, um tipo de [MASK] (a X_1, this is, a type of [MASK])	*V*	0.40	**0.88**	0.80
Hyponym-of	V	como X_1 ou outras maneiras de [MASK] (like X_1 and other manners of [MASK])		0.54	0.64	**0.70**

* Several with correct predictions in the top-10!
  - Suggestions for manual enrichment?

Results in TALES

Other methods

- For discovering related words in static word embeddings (Drozd et al., 2016)

Results in TALES

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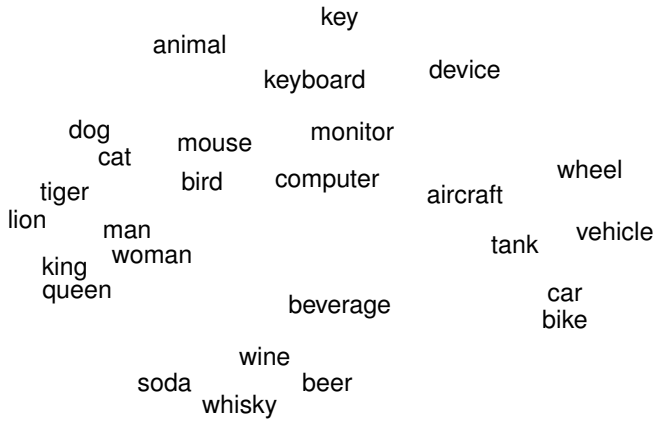
  - 3CosAvg: what is to x_1 as the average of all $(\vec{x'_2} - \vec{x'_1})$?
  - LRCos: what is similar to x_1 and belongs to the class of all x'_2?



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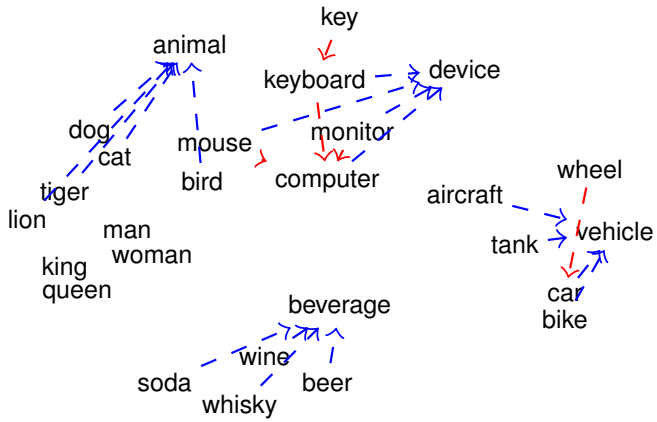

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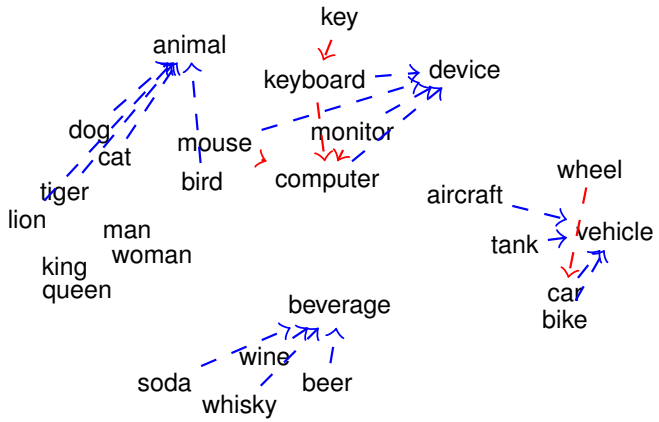

Relation	PoS	BERT-base	BERT-large	Sim	3CosAdd	3CosAvg	LRCos
Synonym-of	N	0.28	0.20	0.28*	0.18*	0.32$^{\times}$	**0.38**$^{+}$
Synonym-of	V	0.12	**0.34**	0.20^{+}	0.12^{+}	0.24^{+}	0.30^{+}
Synonym-of	ADJ	0.06	0.24	0.26*	0.10*	**0.28**$^{+}$	0.26^{+}
Antonym-of	ADJ	0.26	**0.38**	0.20*	0.14*	0.24^{+}	0.28*
Hypernym-of	Abstract	0.22	**0.38**	0.20^{+}	0.06$^{\times +}$	0.20^{+}	0.16^{*+}
Hypernym-of	Concrete	0.20	**0.24**	0.18^{+}	0.10$^{\times}$	0.20*	0.20^{+}
Hypernym-of	V	0.08	0.20	0.14*	0.08$^{\times}$	0.12^{+}	**0.22***
Hyponym-of	Abstract	0.24	**0.40**	0.08*	0.08*	0.10*	0.12*
Hyponym-of	Concrete	**0.60**	0.56	0.10^{+}	0.04$^{\times *+}$	0.14^{+}	0.28$^{\times}$
Hyponym-of	V	**0.24**	0.18	0.14^{+}	0.16*	0.16$^{\times +}$	0.22^{+}

$^{\times}$ GloVe; * word2vec-skip; $^{+}$ word2vec-cbow

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Conclusions & Future

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- Still ...
  - Not as good as static word embeddings for selecting related word from a restricted set
  - Not ready for being used as a LKB, useful for suggesting related words
    - May boost the **enrichment** of wordnets!
    - e.g., any Portuguese WordNet (de Paiva et al., 2016)
    - Best performance for hypernyms of nouns

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- Handcrafted lexical patterns, based on previous work + VARRA
  - Available from: `https://github.com/NLP-CISUC/PT-LexicalSemantics/blob/master/Patterns/BERT_patterns_for_TALES_v2.txt`
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  - Enough coverage?
  - Learn from seeds + corpora? (Bouraoui et al., 2020; Jiang et al., 2020)
- Test other models?
  - e.g., GPT3 (left-to-right instead of bidirectional / masked)

Meanwhile, ChatGPT...

Thank you for you attention.

Questions?

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