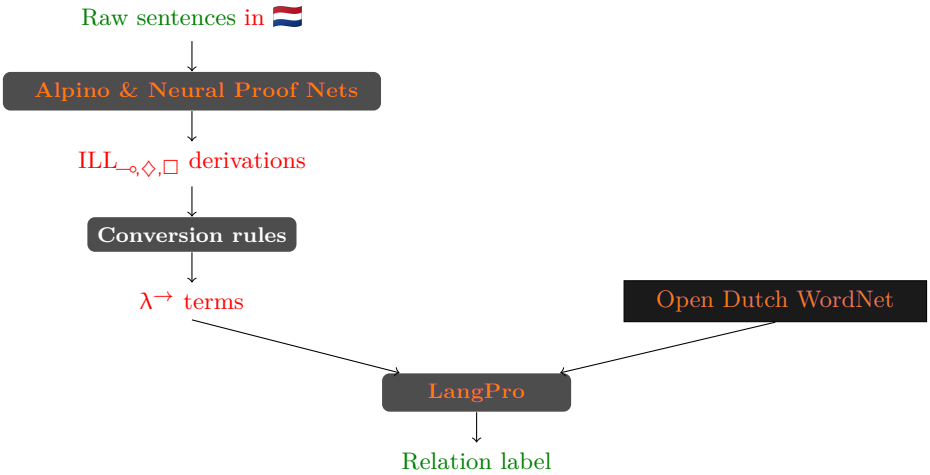
Does Logic-based Reasoning Work for Dutch?

Lasha Abzianidze Konstantinos Kogkalidis

Utrecht Institute of Linguistics OTS, Utrecht University

16-06-2021 @ NaLoMa

Logic-based approach to NLI



The linear λ-calculus

Words are assigned ILL **types**, inductively defined as: $\mathcal{T} := a \mid t_1 \multimap t_2 \mid \Diamond^{\delta} t \mid \Box^{\alpha} t$ where

- a an atom, from a finite set $\mathcal{A}$:
  $\mathtt{np}$, $\mathtt{s_{main}}$, $\mathtt{s_{sub}}$, $\mathtt{pron}$, …
- $t_1 \multimap t_2$ a linear function that **consumes** t_1 to produce t_2
  $\mathtt{np} \multimap \mathtt{s_{main}}$, $\mathtt{np} \multimap (\mathtt{np} \multimap \mathtt{s_{main}})$, $(\mathtt{np} \multimap \mathtt{s_{sub}}) \multimap (\mathtt{np} \multimap \mathtt{np})$, …

Syntactic derivations ≡ **proofs** $\overset{chc}{\equiv}$ functional programs:

$$\tau := c^{t} \mid \left(\tau_1^{t_1 \multimap t_2}\ \tau_2^{t_1}\right)^{t_2} \mid \left(\lambda x^{t_1}.\tau^{t_2}\right)^{t_1 \multimap t_2} \mid \delta_{\Box}\,\tau \mid \delta^{\Box}\,\tau \mid \delta_{\Diamond}\,\tau \mid \delta^{\Diamond}\,\tau$$

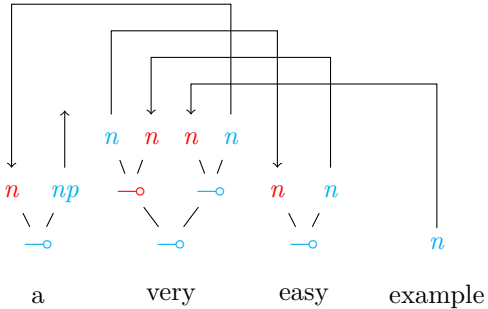
A boy plays:

$$\mathbf{play}^{\Diamond^{\mathrm{su}}\mathtt{np} \multimap \mathtt{s_{main}}} \left(\mathrm{su}^{\Diamond} \left(\left(\det_{\Box}\ \mathbf{a}^{\Box^{\det}(\mathtt{n} \multimap \mathtt{np})}\right) \mathbf{boy}^{\mathtt{n}}\right)\right)$$

Proof Nets

Proof net

a polarized forest (**proof frame**) and a bijection between + and − (axiom links)



`a (very easy example)`

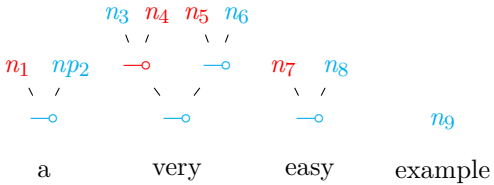
Neural Proof Nets: from sentences to λ-terms

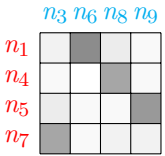
Supertagging

From sentences to proof frames with *seq2seq* transduction

Proving

From proof frames to axiom links with *Sinkhorn-Knopp*





Other ingredients: Alpino & ODWN

Alpino:

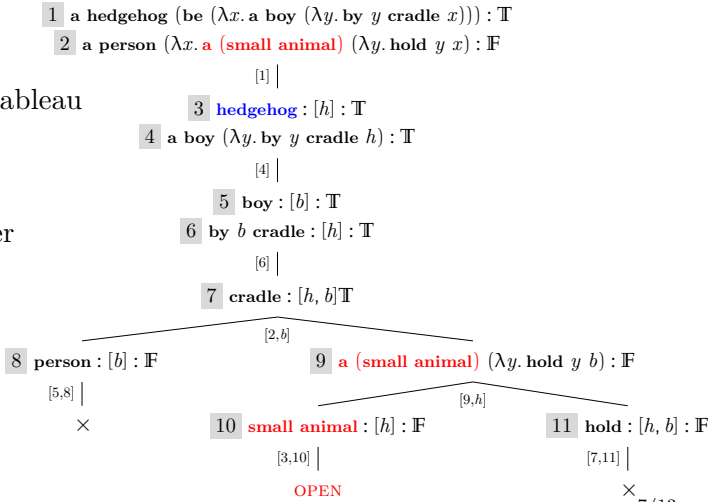
- Stochastic Attribute Value Grammar (HPSG) for Dutch
- Builds dependency structures
- Used for pre-processing Dutch treebanks

Open Dutch WordNet:

- 52K synsets (vs 117K Princeton WN)
- Derived from the Dutch lexical semantic database Cornetto
- We converted ODWN into the prolog format
- Used relations: synonymy, hypernymy, antonymy, similarity, and derivation.

Natural Tableau: proving and learning

- Natural logic + semantic tableau
- Uniform to Ent./Cont.
- Prove with refutation
- Uniform to premise number
- ≈ Syntactic trees
- Native higher-order logic
- Decomposing meaning
- Learning as abduction:
  hedgehog $\sqsubseteq$ **small animal**



Syntactic λ-terms to λ-logical forms

$$\mathbf{play}^{\Diamond^{\mathrm{su}}\mathtt{np}\multimap\mathtt{s}_{\mathtt{main}}}\left(\mathrm{su}^{\Diamond}\left(\left(\mathrm{det}_{\square}\ \mathbf{a}^{\square^{\mathrm{det}}(\mathtt{n}\multimap\mathtt{np})}\right)\mathbf{boy}^{\mathtt{n}}\right)\right) \rightsquigarrow \mathbf{play}^{\mathtt{np},\mathtt{s}}\left(\mathbf{a}^{\mathtt{n},\mathtt{np}}\ \mathbf{boy}^{\mathtt{n}}\right)$$

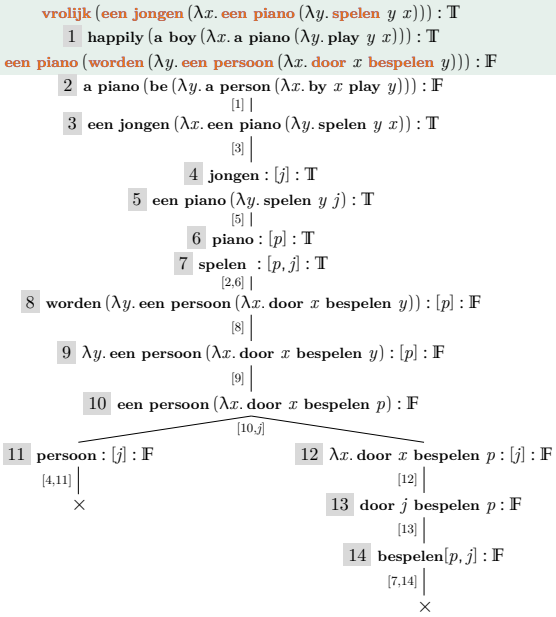
$$\mathbf{large}^{\mathtt{np},\mathtt{np}}\left(\mathbf{brown}^{\mathtt{np},\mathtt{np}}\ \left(\mathbf{a}^{\mathtt{n},\mathtt{np}}\ \mathbf{dog}^{\mathtt{n}}\right)\right) \rightsquigarrow \mathbf{a}^{\mathtt{n},\mathtt{np}}\left(\mathbf{large}^{\mathtt{n},\mathtt{n}}\ \left(\mathbf{brown}^{\mathtt{n},\mathtt{n}}\ \mathbf{dog}^{\mathtt{n}}\right)\right)$$

$$\mathbf{and}\ \left(\lambda x.\,\mathbf{brown}(x\ \mathbf{dog})\right)\left(\lambda y.\,\mathbf{black}(y\ \mathbf{dog})\right)\ \mathbf{no} \rightsquigarrow \mathbf{and}^{\mathtt{np},\mathtt{np},\mathtt{np}}\left(\mathbf{no}\ \left(\mathbf{brown}\ \mathbf{dog}\right)\right)\left(\mathbf{no}\ \left(\mathbf{black}\ \mathbf{dog}\right)\right)$$

$$\mathbf{cut}^{\mathtt{pp},\mathtt{n},\mathtt{np},\mathtt{s}}\ \left(\mathbf{in}^{\mathtt{n},\mathtt{pp}}\ \mathbf{slice}_{\mathtt{n}}\right)\ \mathbf{meat}_{\mathtt{n}} \rightsquigarrow \mathbf{cut}^{\mathtt{pp},\mathtt{np},\mathtt{np},\mathtt{s}}\ \left(\mathbf{in}^{\mathtt{np},\mathtt{pp}}\ \left\{\mathbf{slice}^{\mathtt{n}}\right\}^{\mathtt{np}}\right)\ \left\{\mathbf{meat}^{\mathtt{n}}\right\}^{\mathtt{np}}$$

- Map POS tags and shift to slightly *Generalized* POS tags: UPOS & Penn
- Use only these syntactic categories: $\mathtt{n}, \mathtt{np}_x, \mathtt{s}_x, \mathtt{pp}, \mathtt{pr}$
- Function words $\mapsto$ canonical terms (excl. prepositions)

Natural Tableau for Dutch 🇳🇱



1771 **Entailment**

Een jongen speelt vrolijk piano

---

en piano wordt bespeeld door een persoon

1771 **Entailment**

A boy is happily playing the piano

A piano is being played by a person

Experiments & Results

Parser / POS	Tϵ	Tα:Tϵ	Eϵ	Tα:Eϵ
Alpino / Alpino	72.7	(+9.3)	74.1	(+1.8) 75.9
Alpino / spaCy	74.8	(+9.5)	75.9	(+1.7) 77.6
NPN / Alpino	72.0	(+8.6)	72.8	(+1.5) 74.3
NPN / spaCy	74.3	(+9.1)	75.0	(+1.4) 76.4
LangPro 2×2	76.0	(+9.8)	77.1	(+1.6) 78.7

- POS tagging: spaCy is $1.7_{\leqslant}$ better than Alpino;
- Parsers: Alpino > NPN**?** Sentences parsed 98.6% vs 94.9%;
- The ensemble is $1.2_{\leqslant}$ better than the best monoLP;
- The number of false proofs increases by 4% after αbductive learning.

Comparison to the transformer-based NLI models

Models	All ±Δ	Ent ±Δ	Cont ±Δ
LangPro 2×2	78.7	50.6	66.3
BERTje	82.0 −0.3	86.2 +2.0	86.7 +0.8
mBERT	79.9 +0.7	79.0 +4.7	81.9 +3.1
RobBert	81.7 +0.9	76.9 +6.4	85.3 +1.1

Problems failed by all three DL models but solved by LangPro:

1556 **Entailment**
A man is carrying a tree
A man is carrying a plant

175 **Entailment**
A family is watching a little boy who is hitting a baseball
A boy is hitting a baseball

4092 **Contradiction**
The person is not drawing
A man is drawing a picture

6356 **Contradiction**
A woman in a red dress is putting away an instrument
A woman in a red dress is playing an instrument

Findings: SICK NL & Open Dutch WN

SICK NL is more challenging that the original dataset due to MT:

- Transferred gold labels are not gold:

3181	**Neutral?**	↦	3181	**Neutral**
A man is trekking in the woods			Een man is aan het wandelen in het bos	
The man is not hiking in the woods			De man is niet aan het wandelen in het bos	

- Extra reasoning due to translation shifts:
  drawing a picture ↦ *een tekening maakt* | *tekent een foto*
  dirt bike race ↦ *crossmotorwedstrijd* | *crossmotorrace*.

Lexical relations learned from the training set:

lopen ≡ **rennen**
pizza ⊑ **voedsel**/*food*
halter/*dumbbell* ⊑ **gewicht**/*weight*
leeg/*empty* | **vol**/*full*

Conclusion & Future work

- First Dutch NLI system based on logic
- YES! Logic-based Reasoning Works for Dutch: promising results
- Automatic translation makes the NLI data more challenging

- Employ the Dutch CCG parser
- Qualitative comparison of the Dutch syntactic parsers
- Multilingual LangPro: SICK 🇵🇱🇧🇷 + UD parsers for λLogical Forms