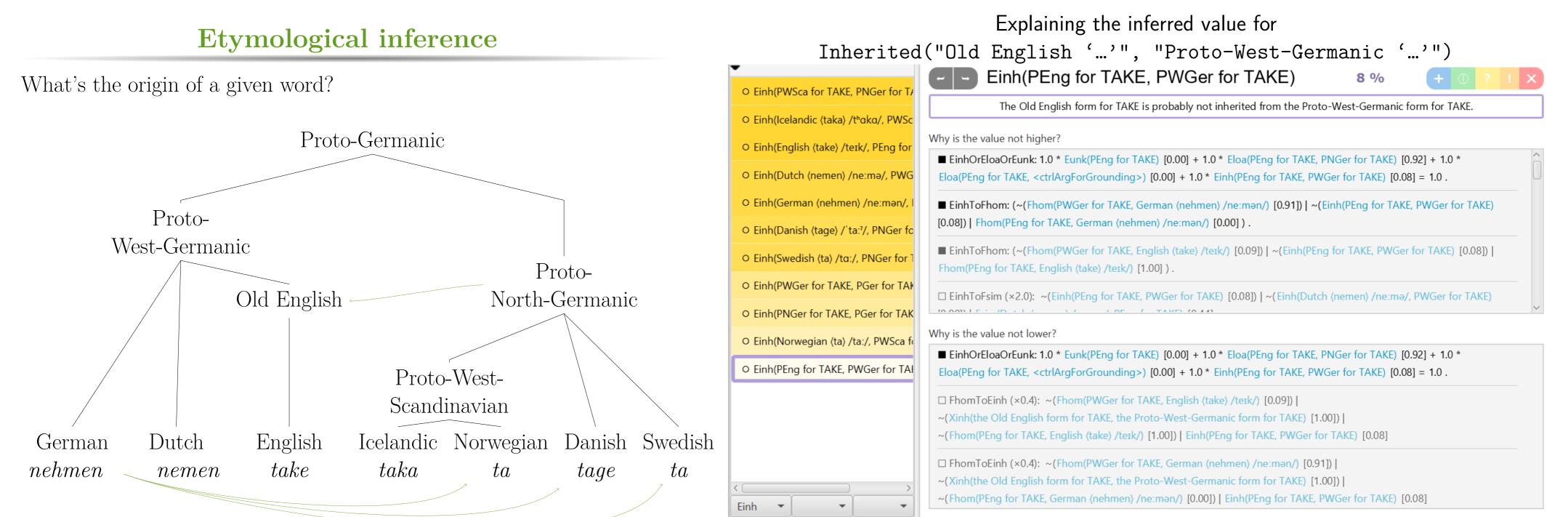
# Navigable atom-rule interactions in PSL models enhanced by rule verbalizations, with an application to etymological inference

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# Probabilistic soft logic (PSL) [1]

- Templating language for a graphical model for statistical relational learning  $\rightarrow$  First-order logic + statistics
- Atom examples: Inherited(X,Y), Similar(X,Y), ...
- Atoms have values  $\in [0; 1]$  that are either fixed or should be inferred
- Rule examples: Similar(X,Y) = Similar(Y,X) ., Inherited(X,Z) & Inherited(Y,Z) & (X != Y) -> Similar(X,Y)
- **Ground** rules/atoms are ones where all variables are replaced by constants
- Rules are **satisfied** if their (in)equalities are fulfilled / if the score of a consequent in an implication is higher than that of the antecedent
- **Distance to satisfaction** quantifies how unsatisfied a rule is:  $\max\{$ antecedent score - consequent score,  $0\}$

Inherited("Icelandic 'taka'", "P-W-Sca '...'") 0.9

- & Inherited("Norwegian 'ta'", "P-W-Sca '...'") 0.9 {0.8
- ("Icelandic 'taka'" != "Norwegian 'ta'") 1.0
- -> Similar("Icelandic 'taka'", "Norwegian 'ta'")
- $\rightarrow$  distance to satisfaction: 0.8 0.7 = 0.1
- Inference goal: minimize all distances to satisfaction

### Rule-atom graph

Inherited Inherited("German 'nehmen'", ToSimilar1 "P-Gmc '...'") Inherited("Dutch 'nemen'", Inherited ToSimilar2 "P-Gmc '...'") Similar("German 'nehmen'", Symmetric Similar1 "Dutch 'nemen'")

O Einh(PWSca for TAKE, PNGer f	
O Einh(Icelandic (taka) /tʰɑkɑ/, PWSc	The Old English form for TAKE is probably not inherited from the Proto-West-Germanic form for TAKE.
	Why is the value not higher?
O Einh(English (take) /teɪk/, PEng for	
	The last step in a word's history will be an inheritance or a borrowing, unless its origin is out of scope. An alternative explanation is that the Old English form for TAKE is borrowed from the Proto-North-Germanic form for TAKE, which is likely.
O Einh(Dutch (nemen) /ne:mə/, PWG	
O Einh(German (nehmen) /ne:mən/, l	■ When we reconstruct an inheritance and assign some belief to the homologue status of the parent, we must assign at leas as much belief to the child's inclusion in the same homologue set. Applying this logic to the homologue set for German
O Einh(Danish (tage) /'ta:'/, PNGer fc	(nehmen) /ne:man/, the Proto-West-Germanic form for TAKE probably belongs to this set but the Old English form for TAKE
	certainly does not, so reconstructing an inheritance becomes problematic.
O Einh(Swedish (ta) /ta:/, PNGer for 1	
O Einh(PWGer for TAKE, PGer for TAk	When we reconstruct an inheritance and assign some belief to the homologue status of the parent, we must assign at least a much belief to the being the child's induction in the same benerate we get. Applying this least to the benerate such as for English (take
	as much belief to the child's inclusion in the same homologue set. Applying this logic to the homologue set for English (take /teɪk/, we are already certain that the Old English form for TAKE belongs to this set. (Therefore, the inheritance relationship
O Einh(PNGer for TAKE, PGer for TAK	ready, we are aneady certain and the ord English form for mate belongs to this set. (Therefore, the infertance readorship
O Einh(Norwegian (ta) /ta:/, PWSca fo	Why is the value not lower?
	The last step in a word's history will be an inheritance or a borrowing, unless its origin is out of scope. An alternative
O Einh(PEng for TAKE, PWGer for TAI	explanation is that the Old English form for TAKE is borrowed from the Proto-North-Germanic form for TAKE, which is likely.
	□ If the forms in a language and its parent are assigned to the same homologue set, this suggests that the form in the child
	language was inherited. Applying this logic to the homologue set for English (take) /teɪk/, since neither homology judgment
	is entirely unlikely (the Old English form for TAKE is certainly a homologue of English (take) /teɪk/ although the
	Proto-West-Germanic form for TAKE is probably not a homologue of English (take) /teɪk/), we cannot disregard the
	possibility that the Proto-West-Germanic form for TAKE is inherited from the Old English form for TAKE.
	☐ If the forms in a language and its parent are assigned to the same homologue set, this suggests that the form in the child

## Rule activity

- A rule is **active** with respect to an atom if
- it is dissatisfied

 $\leq$ 

0.7

X

• it *would* be dissatisfied if the atom's value were changed slightly

Active rules directly contribute to the MAP estimate and thus the atoms' exact values!

• GUI: black (active) vs. grey (inactive) rules

# Try it out!

github.com/jdellert/ psl-infrastructure github.com/verenablaschke/ psl-ragviewer



## Upward/downward pressure

Each rule-atom link exerts up- and/or downward **pressure** on the value of the atom:

Inherited(X,Z) & Inherited(Y,Z) & (X!=Y)  $\rightarrow$  Similar(X,Y)

- Can explain why an atom value is higher/lower than expected
- GUI: "Why is the value not higher/lower?"

### Atom/rule verbalization

- Expressing the mechanics of each ground rule in terms of domain-specific natural language (useful for domain experts who don't know PSL)
- Based on templates
- Introductory sentence (idea behind the rule) & details specific to...
  - the rule grounding and atom value
  - the upward/downward pressure on the atom
  - the position of the atom within the rule
- GUI: toggle between internal (PSL) view and verbalized view

#### References

[1] Stephen H. Bach, Matthias Broecheler, Bert Huang, and Lise Getoor. Hinge-loss Markov random fields and probabilistic soft logic. Journal of Machine Learning Research, 18(109):1-67, 2017.

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