Is automatic cognate detection good enough for phylogenetic inference?

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Jena, CESC 2017

September 13, 2017

WORDS BONES GENES TOOLS
Tracking Linguistic, Cultural, and Biological Trajectories of the Human Past

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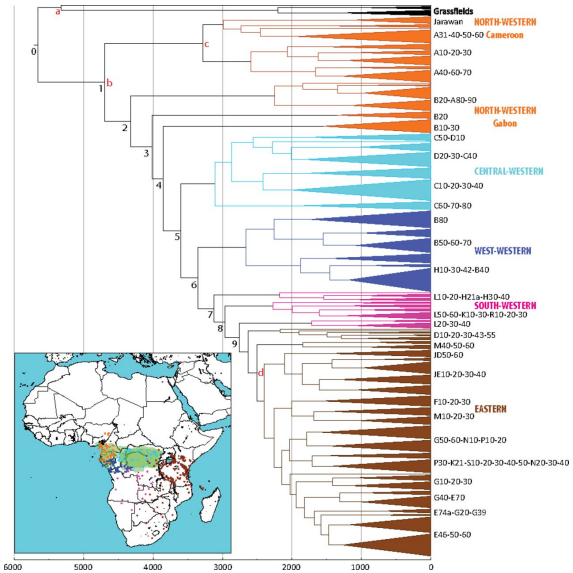
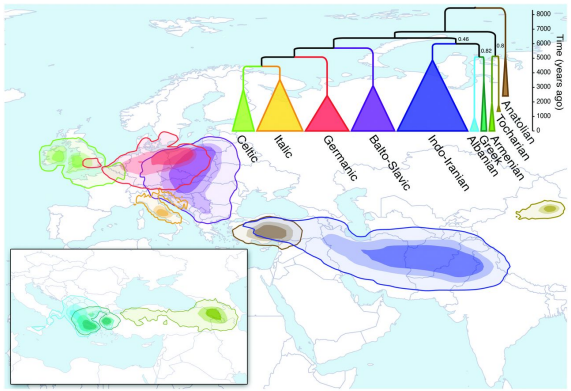
Computational historical linguistics

- massive progress within past 15 years
- automated language classification
- inferring time depth and homeland of language families
- automatic reconstruction of proto-languages
- discovery of statistical patterns in language change
- ...



(Grollemund et al, 2015)



(Bouckaert et al, 2012)

Computational historical linguistics

Manual cognate judgements

- most work depends on manually coded cognate judgments on Swadesh lists
  - labor intensive
  - subjective
  - not fully replicable
  - induces bias in favor of well-studied language families

Computational historical linguistics

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language	*iso*	*gloss*	*gloss_id*	*transcr.*	*cogn._class*
ELFDALIAN	qov	woman	962	ˈkɛ̀lɪŋg	woman:Ag
DUTCH	nld	woman	962	vrɑu	woman:B
GERMAN	deu	woman	962	fraŭ	woman:B
DANISH	dan	woman	962	ˈg̊ʰvenə	woman:D
DANISH_FJOLDE		woman	962	kvinʲ	woman:D
GUTNISH_LAU		woman	962	ˈkvɪnːˌfolk	woman:D
LATIN	lat	woman	962	ˈmulier	woman:E
LATIN	lat	woman	962	ˈfeːmina	woman:G
ENGLISH	eng	woman	962	wʊmən	woman:H
GERMAN	deu	woman	962	vaĭp	woman:H
DANISH	dan	woman	962	ˈd̥ɛːmə	woman:K

- The goal of automated cognate detection is to do this automatically

Datasets

Dataset	Words	Conc.	Lang.	Families	Cog.	Div.
ABVD (Greenhill et al., 2008)	12414	210	100	Austronesian	3558	0.27
Sino-Tibetean (Peiros, 2004)	8694	110	81	Sino-Tibetean	1128	0.13
IELex (Dunn, 2012)	11479	208	52	Indo-European	2459	0.20

Expert Trees

- Expert trees were obtained from Glottolog (Hammarström et al., 2015)

Glottolog

Glottolog provides a comprehensive catalogue of the world's languages, language families and dialects. [...] The languoids are organized via a genealogical classification (the Glottolog tree) that is based on available historical-comparative research[...]. (http://glottolog.org/)

Automated Cognate Detection

LexStat

- algorithm first propose in List (2012) and then further enhanced in List (2014), List et al. (2016) and List et al. (2017)
- the algorithm is generally based on the alignment-based workflow for cognate detections
- implemented as part of LingPy (lingpy.org,List and Forkel (2016))

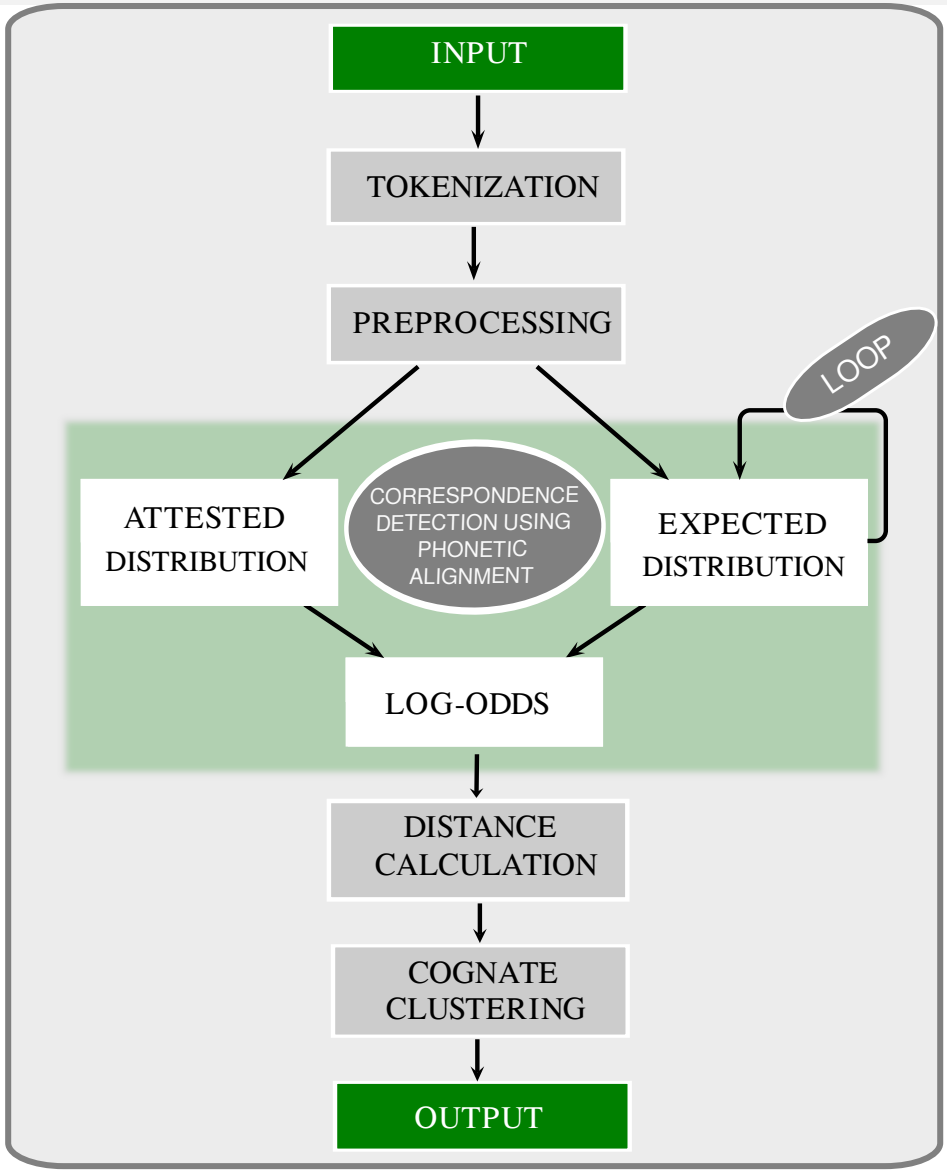
SVM

- Classification based approach (Jäger and Sofroniev, 2016; Jäger et al., 2017)
- A pair of words is classified as cognate or not based on a feature vector describing this pair
- Implementation: http://www.evolaemp.uni-tuebingen.de/svmcc/

LexStat

- scoring functions for alignments are computed *individually* for each language pair, modeling regular sound correspondences in classical linguistics
- scores for both global and local alignment analyses are combined and agglomerated
- alignment algorithm is sensitive for morpheme boundaries if they are annotated (*secondary alignment*, List (2014))
- sequences are represented as *multi-tiered structures* which allows to handle *prosodic context*
- agglomerative clustering procedure has been replaced by a community detection algorithm (Infomap, Rosvall and Bergstrom (2008))

LexStat



LexStat Algorithm (List 2014)

LexStat: Cognate Set Partitioning

A

		GREEK	GERMAN	ENGLISH	RUSSIAN	POLISH
GREEK	çeri	0.00	0.72	0.69	0.73	0.77
GERMAN	hant	0.72	0.00	0.03	0.91	0.70
ENGLISH	hænd	0.69	0.03	0.00	0.91	0.68
RUSSIAN	ruka	0.72	0.91	0.91	0.00	0.20
POLISH	rɛ̃ŋka	0.77	0.70	0.68	0.20	0.00

List et al. (2017)

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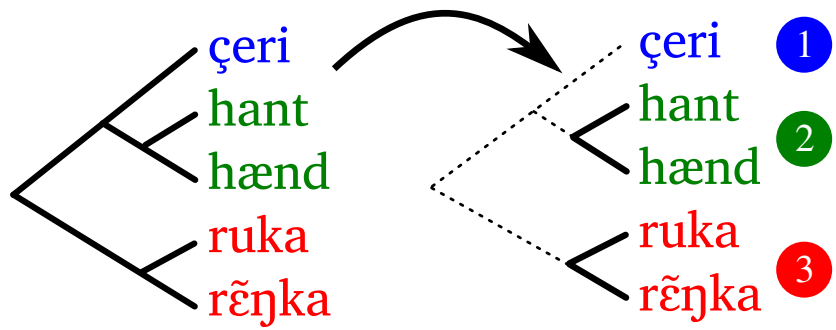

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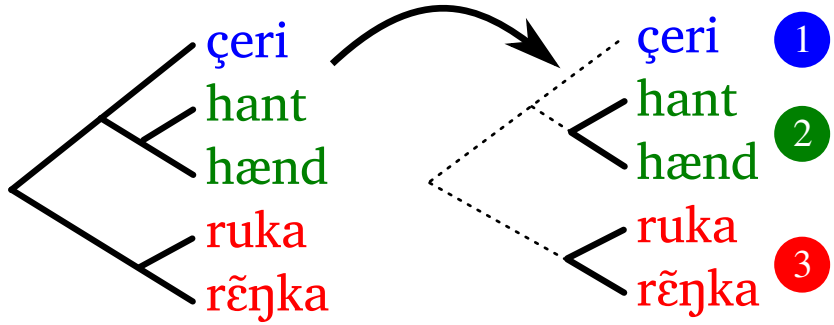

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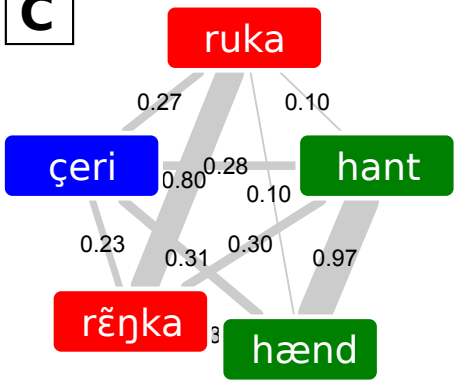

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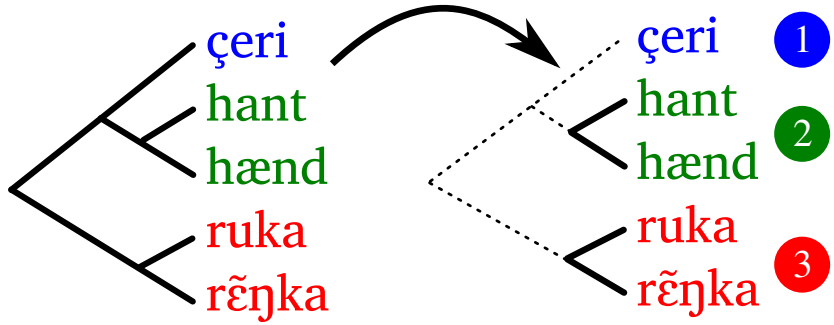

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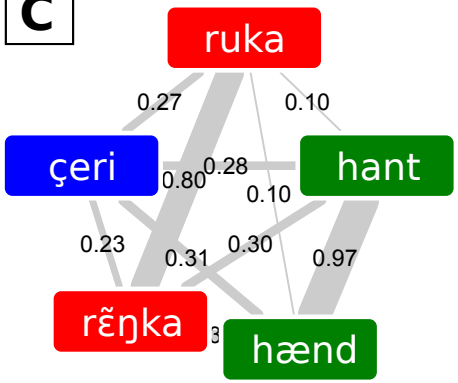

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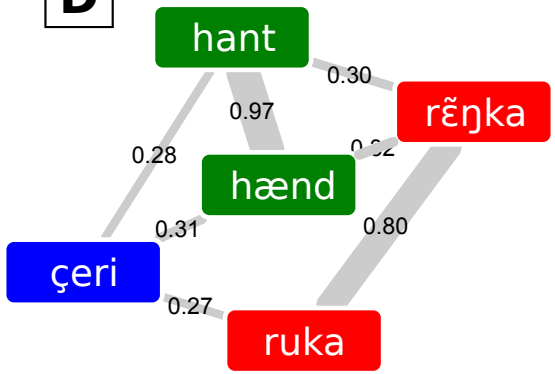

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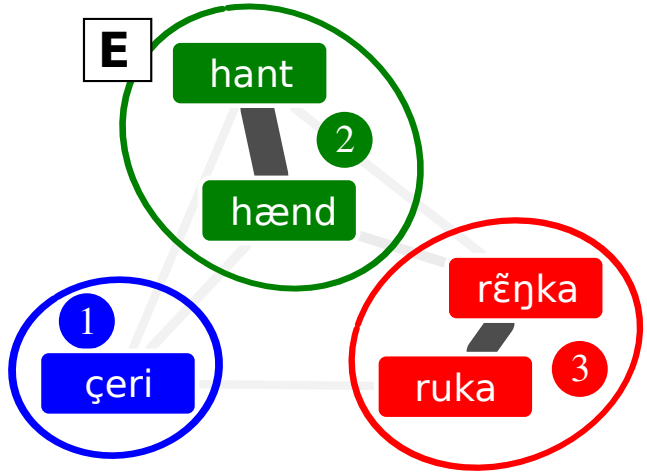
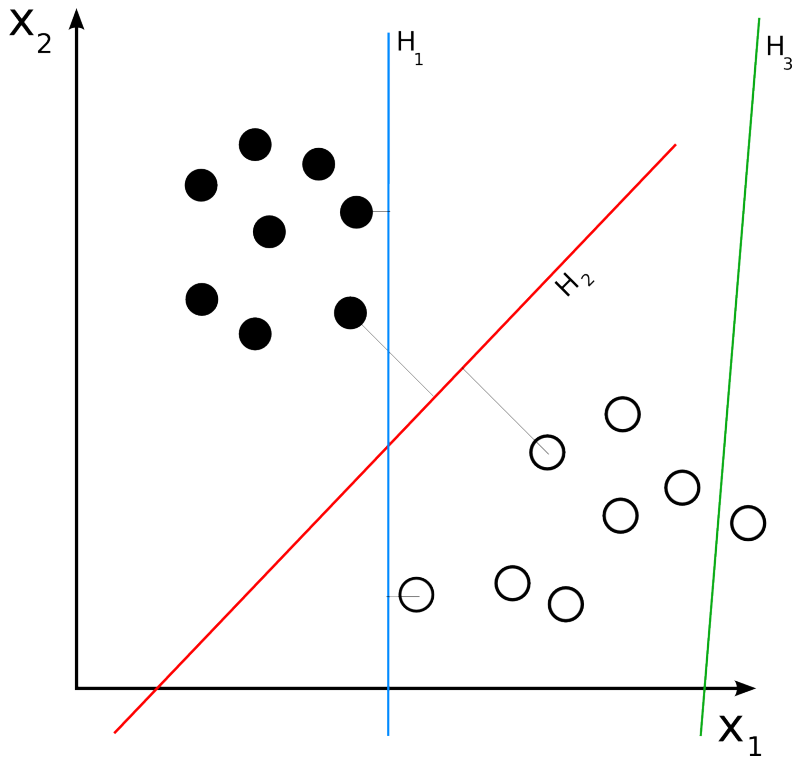


List et al. (2017)

SVM



via Wikimedia Commons

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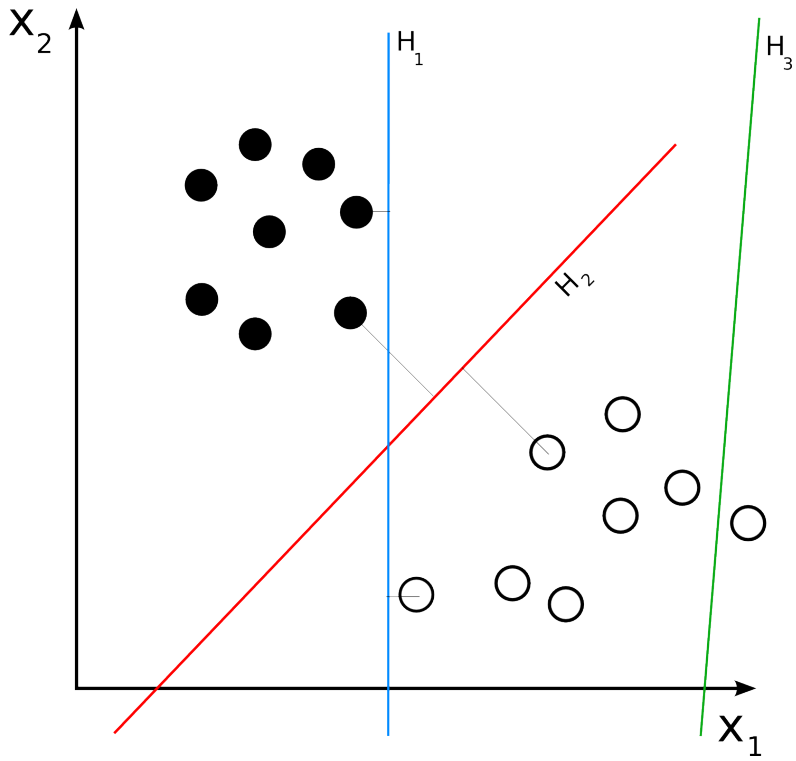


via Wikimedia Commons

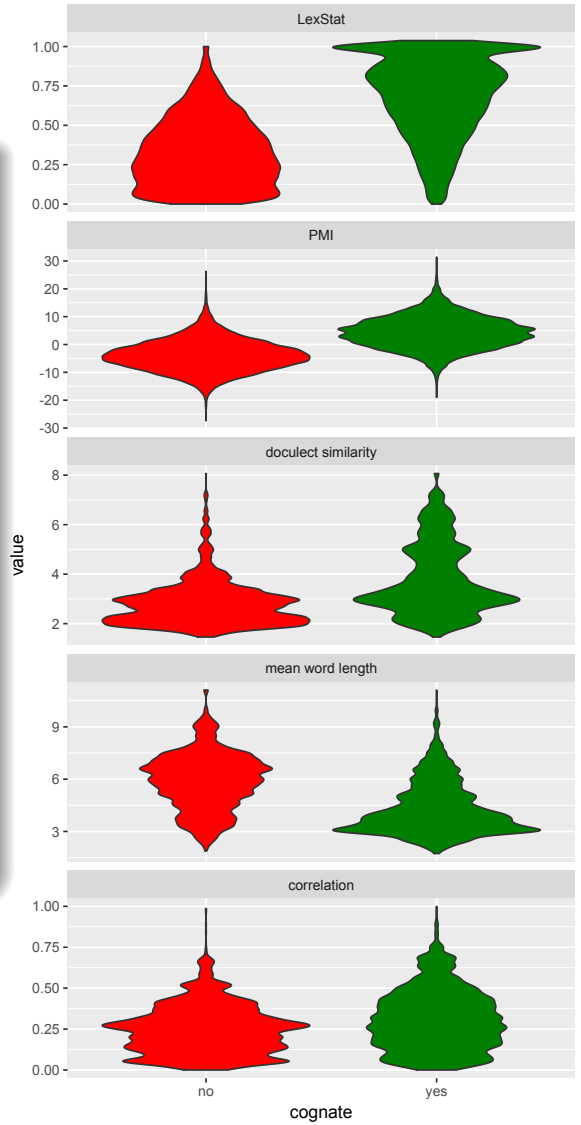
Model selection

- each synonymous word pair is a data point
- cognate (yes/no) as dependent variable
- Feature selection
  - seven features from (Jäger and Sofroniev, 2016) + LexStat similarity as candidate features
  - feature selection via cross-validation on training data

SVM

Model selection

- five informative features
  - LexStat similarity
  - PMI similarity
  - doculect similarity
  - measures of concept stability
    - mean word length
    - correlation between string similarity and doculect similarity
- linear kernel



Performance of the ACD Methods

- All scores are B-Cubed scores (Bagga and Baldwin, 1998)

dataset	*Precision*		*Recall*		*F-score*	
	LexStat	*SVM*	*LexStat*	*SVM*	*LexStat*	*SVM*
Indo-European	0.896	0.877	0.750	0.770	0.817	0.820
Austronesian	0.791	0.781	0.801	0.855	0.796	0.817
Sino-Tibetean	0.928	0.848	0.301	0.409	0.455	0.552

Observations

- current methods for automatic cognate detection are fairly accurate
- they are objective and replicable
- they make it much easier to obtain large datasets for cross-linguistic historical language comparison

Question: Are they good enough for phylogenetic inference?

Mr. Bayes

- An (ideal) phylogenetic model consists of
  1. Phylogenetic tree + branch length
  2. (Explicit) model of character evolution along the branches of the tree
- Mr. Bayes (Ronquist et al., 2012) provides a framework for such phylogenetic analysis
- Uses Markov Chain Monte Carlo methods to estimate a posterior of the parameters of the model

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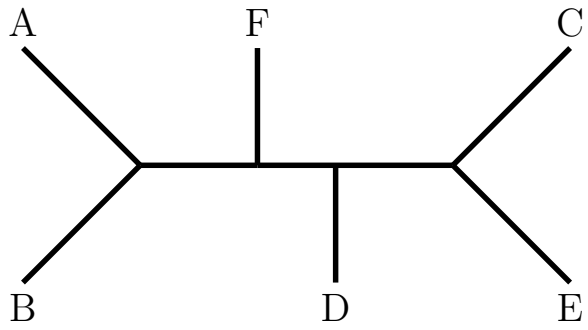
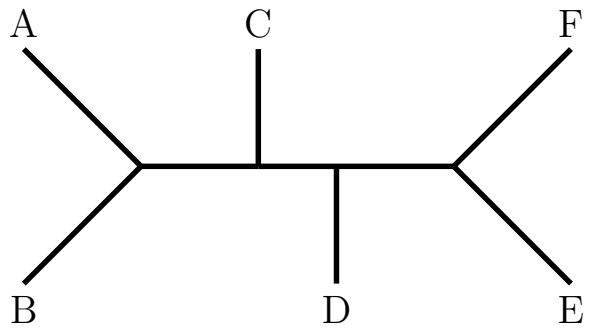
Generalized Quartet Distance

- number of quartets not having the same topology in both trees divided by the number of quartets in the expert tree (Pompei et al., 2011)

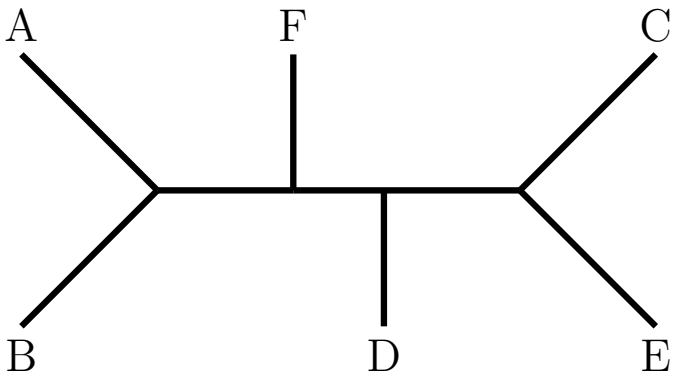


Expert Tree



Inferred Tree

Generalized Quartet Distance



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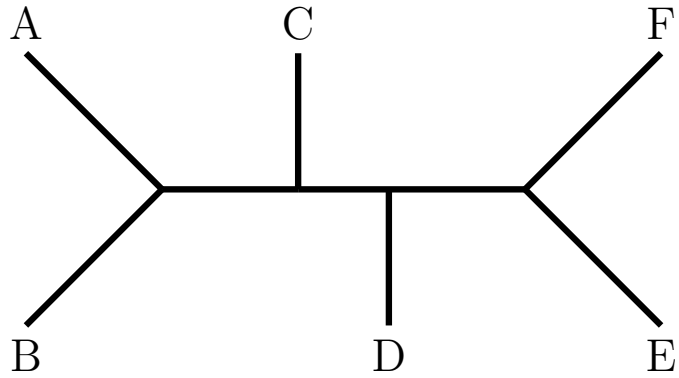

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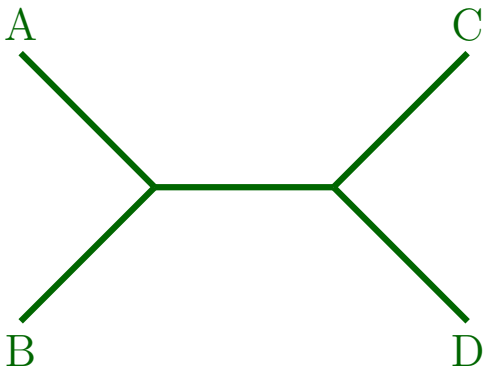
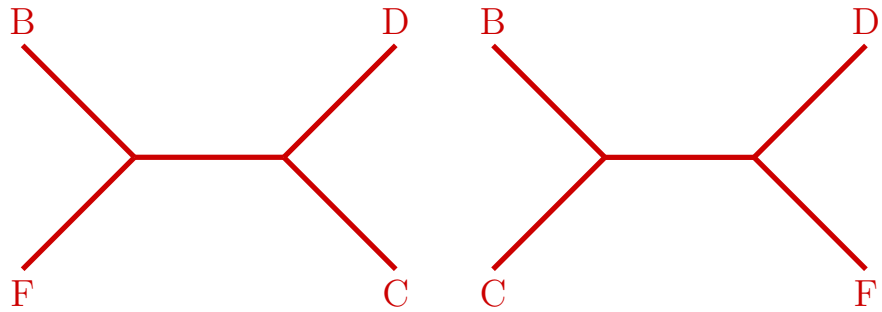


Same configuration

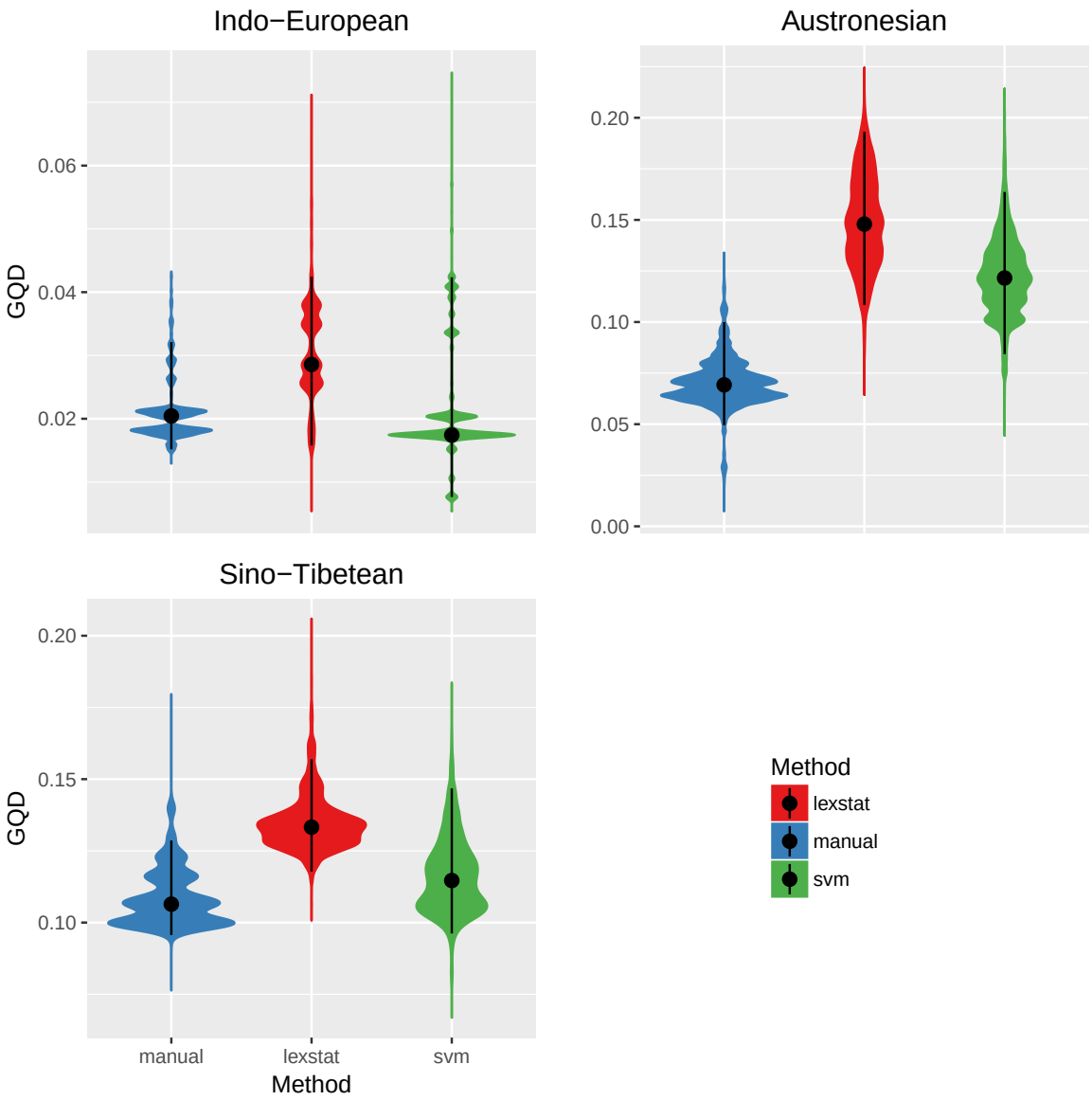


Different configuration

	manual	LexStat	SVM
Austronesian	**0.069 (0.050-0.100)**	0.133 (0.108-0.193)	0.121 (0.084-0.164)
Sino-Tibetan	**0.106 (0.096-0.129)**	0.133 (0.118-0.157)	0.115 (0.096-0.147)
Indo-European	**0.020 (0.015-0.032)**	0.029 (0.016-0.042)	0.017 (0.008-0.042)

Median and HPD Interval (95%)

Results


Indo−European
Austronesian
Sino−Tibetean
GQD
0.06
0.04
0.02
0.20
0.15
0.10
0.05
0.00
manual
lexstat
svm
Method
Method
lexstat
manual
svm

Conclusion

- The performance is close to manual judgments (especially for Indo-European)
- The supervised ACD method (SVM) performs better than the unsupervised method (LexStat)
- Trees from manually annotated cognates are not perfect either
  1. Rethink tree inference algorithms for linguistics?
  2. Rethink cognate annotation?

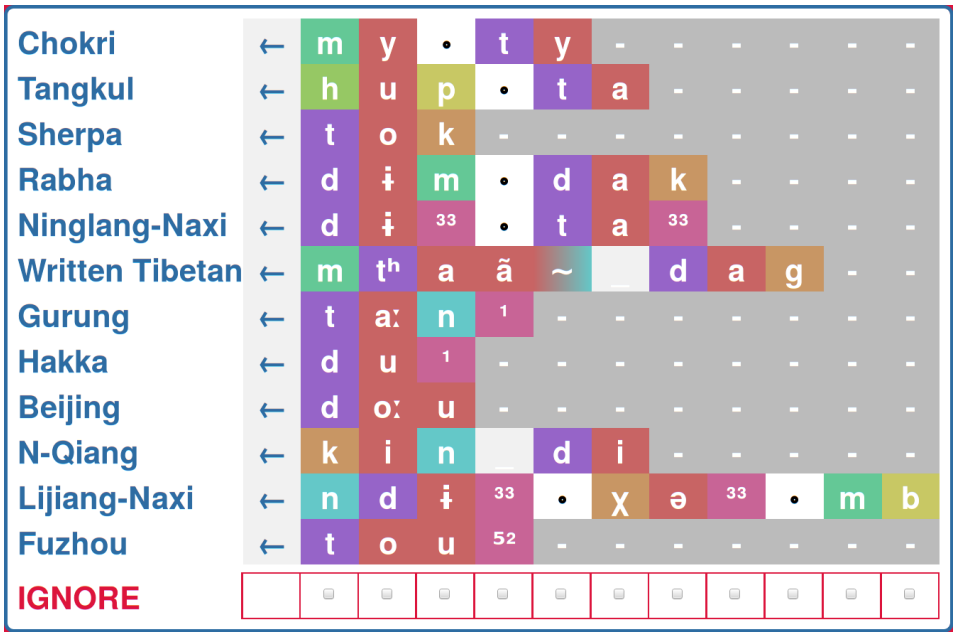
Outlook

How can we improve?

- Enhance the quality of our datasets (Sino-Tibetan is highly problematic, IELex will be superseded by COBL, ABVD can be improved by looking into sub-branches).
- Test expert cognate trees vs. autocogs on better data (COBL?).
- Enhance annotation of lexical differences (partial cognates are needed, List 2016, morphological differences in data should be annotated).
- Enhance phonological annotation (standardized cross-linguistic transcription systems).
- Enhance lexical coverage in the data (increase size of concept lists, increase internal coverage per language).

Outlook

Concept “all” in some Sino-Tibetan languages:



Annotating alignments with the EDICTOR (List, 2017).

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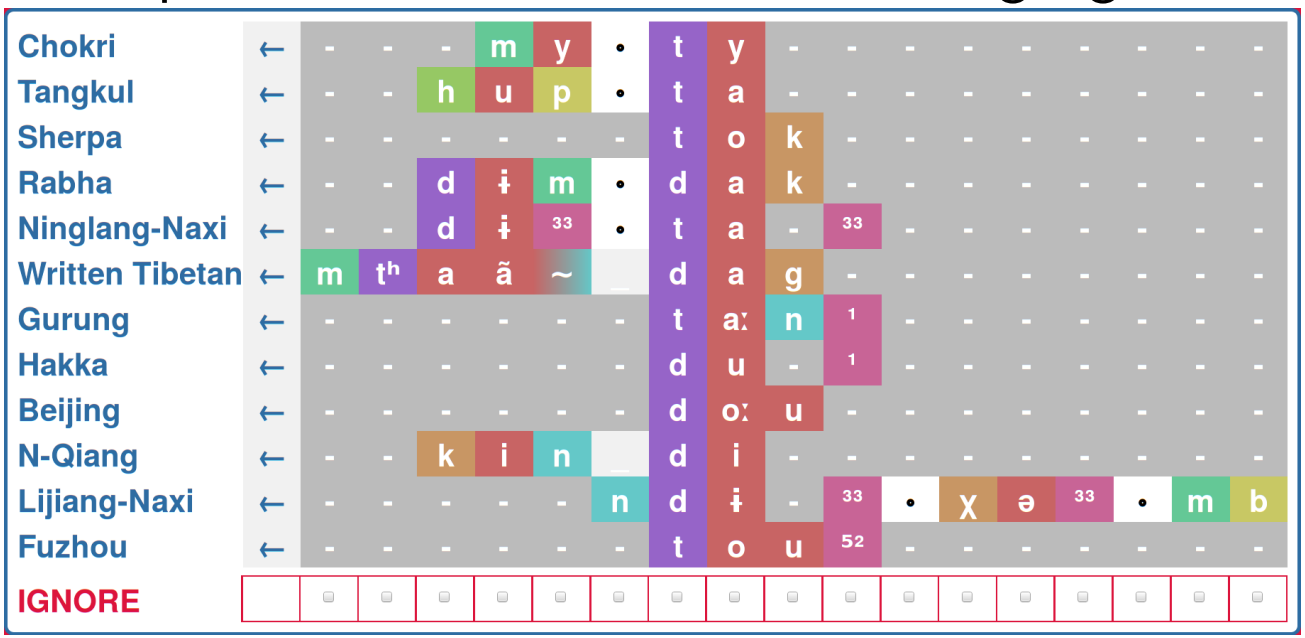

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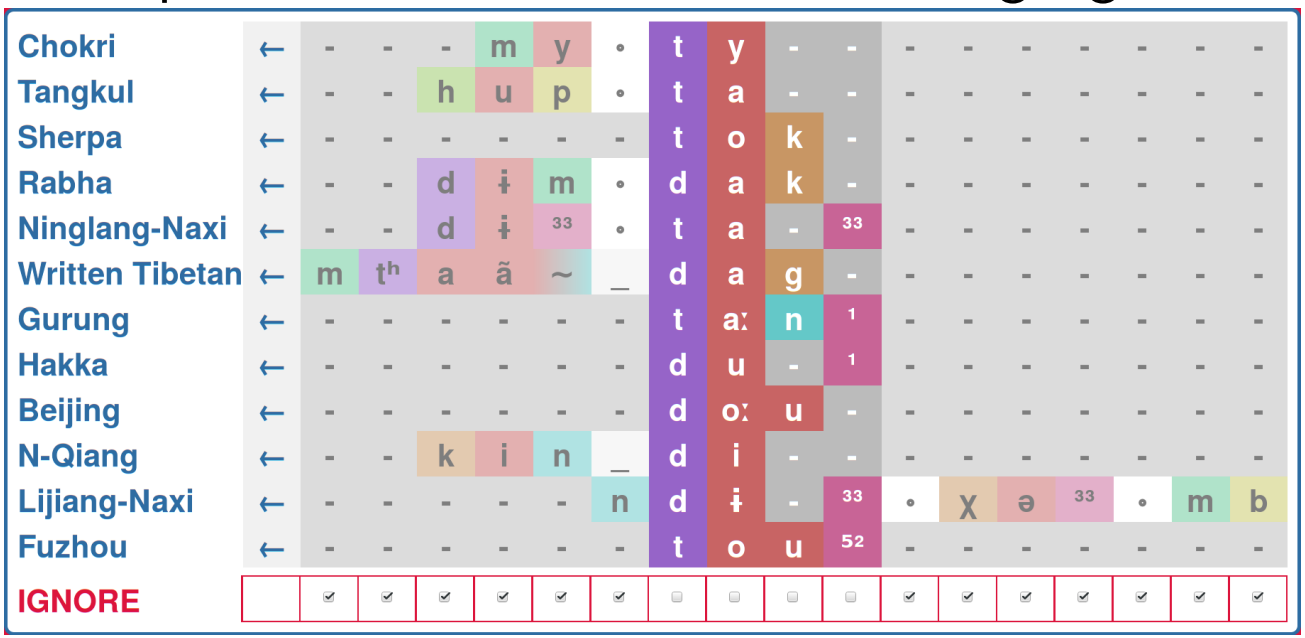

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