A Reproducibility Study on Quantifying Language Similarity: The Impact of Missing Values in the URIEL Knowledge Base

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Motivation

Understanding Language Similarity

- Essential for multilingual NLP applications.
- No consensus on best methods for low-resource languages (LRLs).

Challenges with URIEL Database

- URIEL (Littell et. al., 2017) is a typological knowledge base that aggregates linguistic information from various sources
- Inconsistencies of definitions and missing values affect reliability of language similarity measurements.

Our Contributions

- Identify areas for improvement for URIEL and its lang2vec tool for calculating language similarity.
- Analyze feature coverage across languages
- Investigated how URIEL is utilized in current NLP research, highlighting the dependency on its accuracy.

Literature Review

Usage of Language Similarity

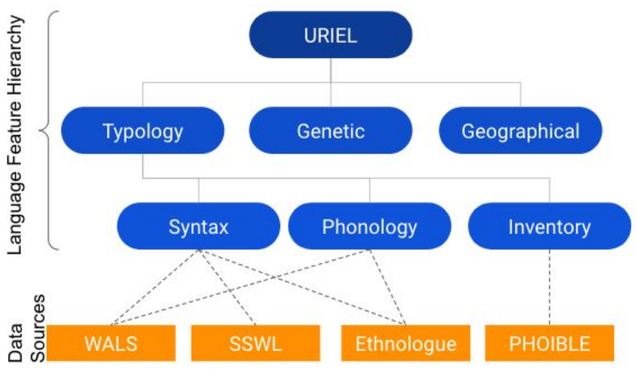
- **Cross-lingual modelling and learning** (Lauscher et al., 2020)
- **Performance prediction** (Patankar et al., 2022, Xia et al., 2020, Srinivasan et al., 2021)
- **Cross-lingual transfer and language translation** (Lin et al., 2019, Huang et al., 2021)
- **Integration with language models** (Üstün et al., 2020, Adilazuarda et al., 2024)

Observed Limitation

- Predicted values exhibit noticeable clusters due to biases introduced by family-based prediction of missing values (Ponti et al., 2019).

URIEL/lang2vec's Method

1 Collect information from various sources



Contains missing values!

Fig. 1: URIEL feature hierarchy and data sources

2 Take an aggregate of the different sources

- Union
- Average
- *k*-nearest neighbor (KNN)

Unclear which one to use in which scenario!

*k*NN details not provided

3 Compute the distance of feature vectors of the two languages

- **lang2vec documentation:** Cosine distance

$$D_C(u, v) := 1 - S_C(u, v)$$

- **URIEL documentation:** Angular distance

$$D_\theta(u, v) := \frac{1}{\pi} \arccos(S_C(u, v))$$

where $S_C(u, v) := \frac{u \cdot v}{\|u\| \|v\|}$

Conflicting definition

Maybe regularize?

Reproducibility

Handling Missing Values

By inspection, the following approach is most likely used by URIEL to handle missing values:

- **All values missing:** Replace entire vector with [1, 1, …, 1].
- **Partial values missing:** Replace missing entries with 0.

Percentage of Reproducible Distances

Aggregate Vector	Distance Metric	syntactic	phonological	inventory
union	cosine	23.90%	61.62%	40.04%
	reg_angular	**93.96%**	**95.42%**	**99.45%**
average	cosine	23.95%	61.62%	40.04%
	reg_angular	89.82%	95.21%	90.53%
knn	cosine	0.39%	1.45%	0.12%
	reg_angular	2.46%	2.53%	9.70%

- Union vector with regularized angular distance achieves the highest reproducibility of pre-calculated distances.
- Union and average vectors are identical for many languages ⇒ Similar reproducibility.
- Some distance values cannot be reproduced using any method- unclear factor of irreproducibility.

Feature Coverage

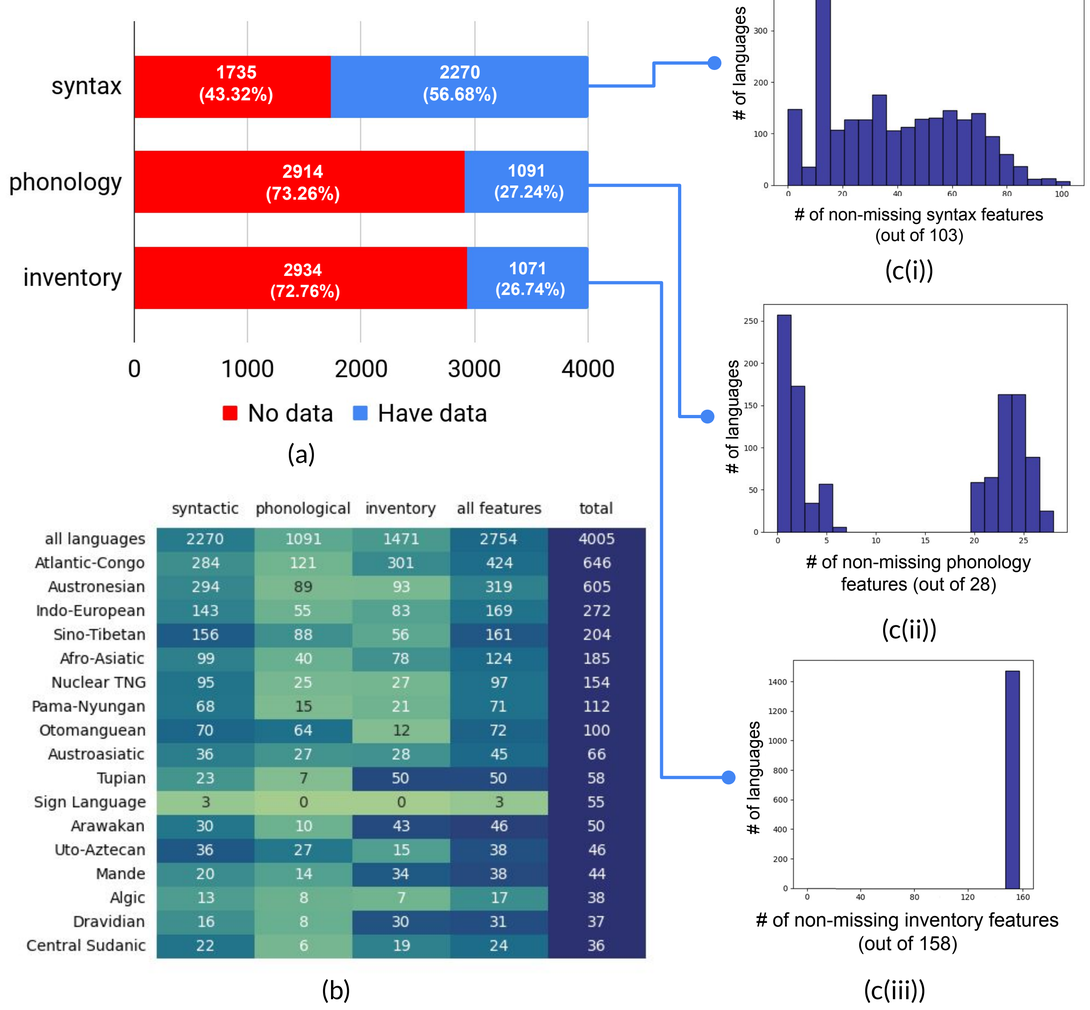


Fig. 2: Feature coverage across 4005 languages (overall: a; by family: b) and distribution based on number of non-missing features in union vector for syntax_union (c(i)), phonology_union (c(ii)), and inventory_union (c(iii)), excluding languages with empty feature vectors.

Conclusion & Next Step

- **Unclear Definitions:** Definitions of distance values in the documentation is unclear; some values remain irreproducible.
- **Missing Values:** Approaches to handle missing values has no clear justification- affects validity of language distances involving LRLs.
- **Low Coverage:** 31.24% of languages lack feature information, making provided distances meaningless.
- **Future Directions:**
  - Establish clear guidelines for acceptable levels of missing data.
  - Explore alternative similarity measurement for LRLs.

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References

- Patrick Littell, David R. Mortensen, Ke Lin, Katherine Kairis, Carlisle Turner, and Lori Levin. 2017. URIEL and lang2vec: Representing languages as typological, geographical, and phylogenetic vectors. In Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics: Volume 2, Short Papers, pages 8–14, Valencia, Spain. Association for Computational Linguistics.