CS11-737: Multilingual Natural Language Processing

Typology: The Space of Languages

Yulia Tsvetkov

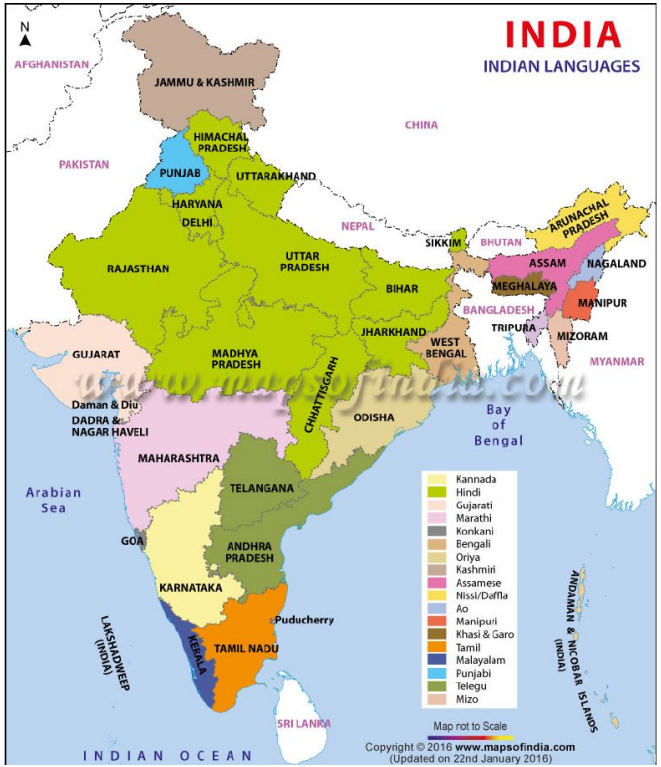
Carnegie Mellon University
Language Technologies Institute

Linguistic diversity: ~7000 languages

Low resource languages

There are about 460 languages in India.

1.38 billion people



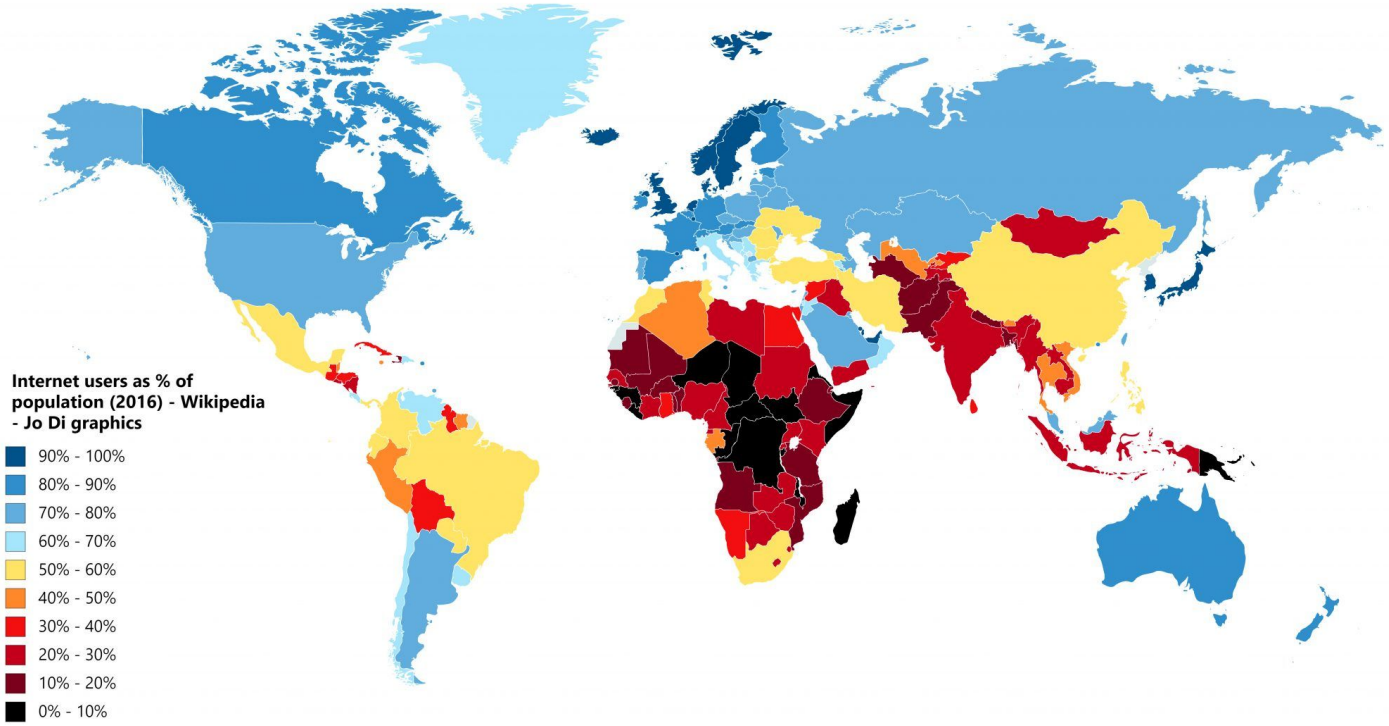
Low resource languages

Africa is a continent with a very high linguistic diversity:

there are an estimated 1.5-2K African languages from 6 language families.

1.33 billion people

Low-resource/multilingual NLP



https://jodi.graphics/2018/05/11/internet-users-as-of-population/

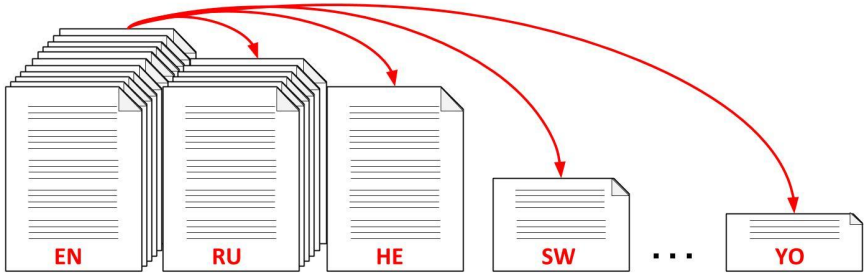
40% of world's population: South Asia - 1.75 billion, Africa - 1.3 billion, etc.

Approaches to low-resource/multilingual NLP

- Manual curation and annotation of large-scale resources for thousands of languages in infeasible or prohibitively expensive

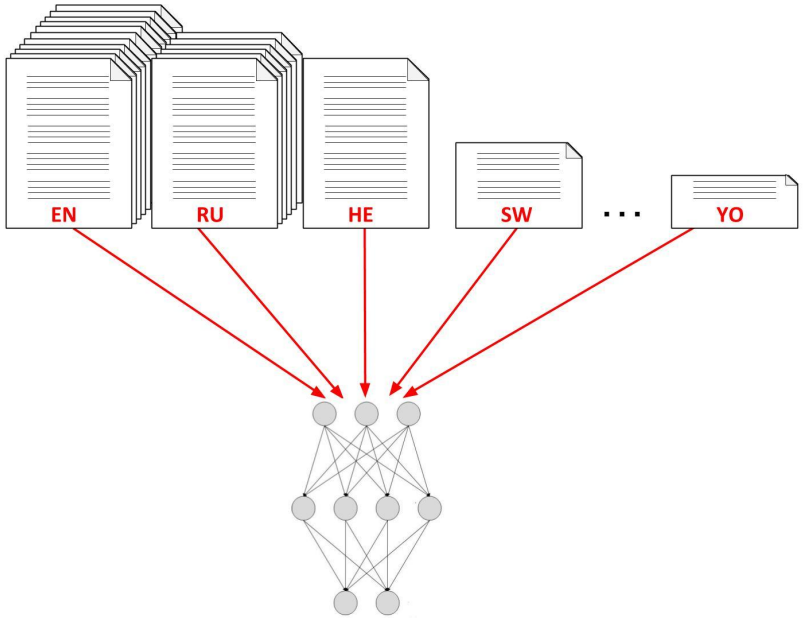
- Unsupervised learning (Snyder and Barzilay 2008; Cohen and Smith, 2009; Snyder, 2010; Vulić, De Smet, and Moens 2011; Spitkovsky et al., 2011; Goldwasser et al., 2011; Titov and Klementiev 2012; Baker et al., 2014, and many others)

Approaches to low-resource/multilingual NLP



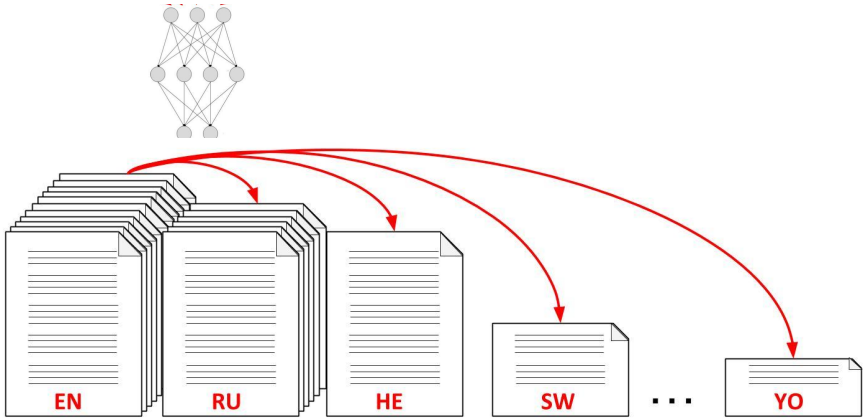
- Cross-lingual transfer learning – transfer of resources and models from resource-rich source to resource-poor target languages
  - Transfer of annotations (e.g., POS tags, syntactic or semantic features) via cross-lingual bridges (e.g., word or phrase alignments)
  - Transfer of models – train a model in a resource-rich language and adapt (e.g. fine-tune) it in a resource-poor language
- Zero-shot learning – train a model in one domains and assume it generalizes more or less out-of-the-box in a low-resource domain
- Few shot learning – train a model in one domain and use only few examples from a low-resource domain to adapt it

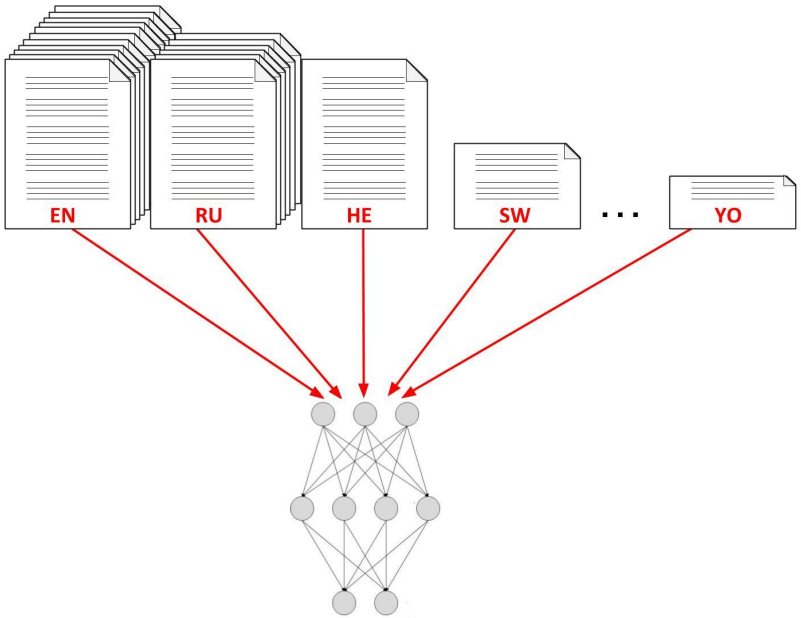
Approaches to low-resource/multilingual NLP



- Joint multilingual learning – train a single model on a mix of datasets in all languages, to enable data and parameter sharing where possible

Choosing transfer languages





Lin, Y.H. et al. 2019. Choosing Transfer Languages for Cross-Lingual Learning. In Proc. ACL.
https://arxiv.org/pdf/1905.12688.pdf

How to define similarity across languages?

- Word overlap and sub-word overlap
  - Russian – Русский
  - Ukraininan – Українська
  - Chinese – 中文
  - Korean – 한국어
  - Vietnamese – Tiếng Việt
  - Georgian – ქართული
  - Japanese – 日本人
  - Turkish – Türk
  - Hebrew – עִבְרִית
  - Arabic – عربى
  - Hindi – हिन्दी
  - Xhosa – isiXhosa
- Areal similarity www.glottolog.org
- Demographic similarity

Genealogical similarity

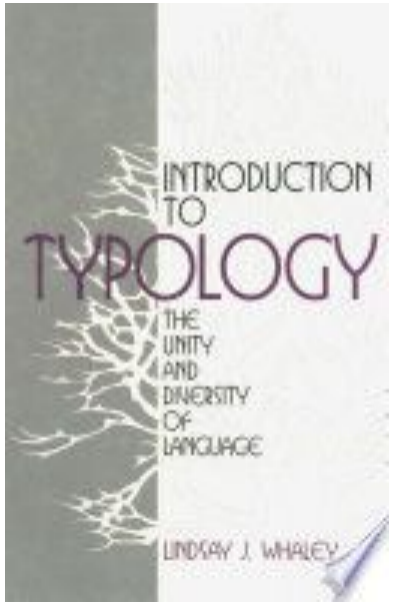
1. Niger–Congo (1,542 languages) (21.7%)
2. Austronesian (1,257 languages) (17.7%)
3. Trans–New Guinea (482 languages) (6.8%)
4. Sino-Tibetan (455 languages) (6.4%)
5. Indo-European (448 languages) (6.3%)
6. Australian [dubious] (381 languages) (5.4%)
7. Afro-Asiatic (377 languages) (5.3%)
8. Nilo-Saharan [dubious] (206 languages) (2.9%)
9. Oto-Manguean (178 languages) (2.5%)
10. Austroasiatic (167 languages) (2.3%)
11. Tai–Kadai (91 languages) (1.3%)
12. Dravidian (86 languages) (1.2%)
13. Tupian (76 languages) (1.1%)

www.ethnologue.com

Typological similarity

- Linguistic typology: classification of languages according to their functional and structural properties
  - explains common properties across languages
  - explains structural diversity across languages

“The classification of languages or components of languages based on shared formal characteristics.”



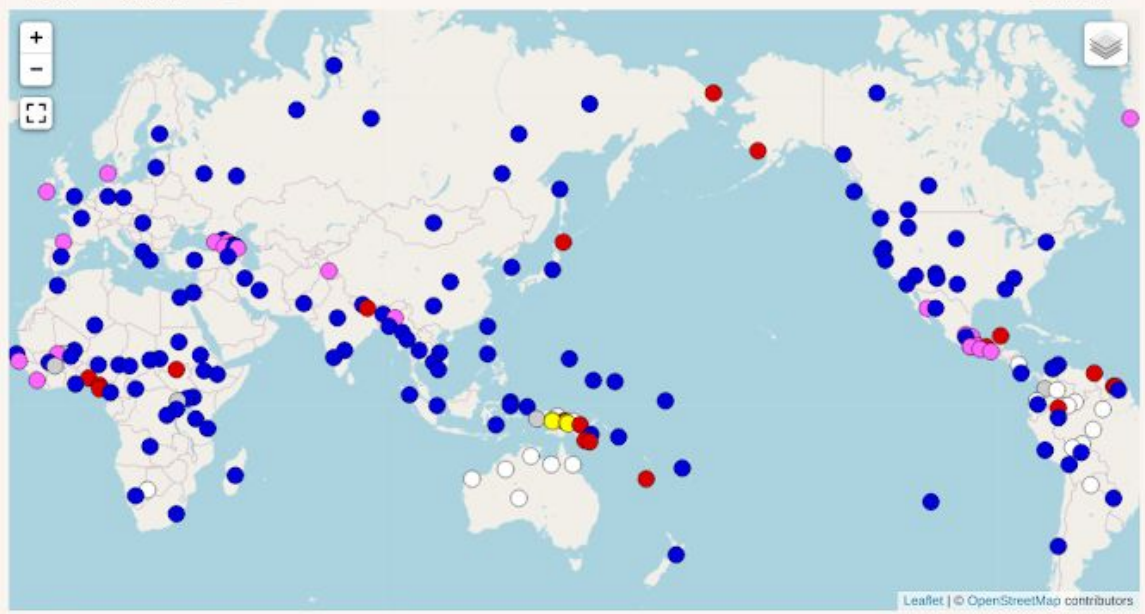
Linguistic typology example: phonology

French **Arabic**

Place → / ↓ Manner	Bilabial	Labio-dental	Linguo-labial	Dental	Alveolar	Palato-alveolar	Retroflex	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngeal / Epiglottal	Glottal
Nasal	m̥ m	ɱ	n̪̊ n̪		n̥ n		ɳ̊ ɳ		ɲ̊ ɲ	ŋ̊ ŋ	ɴ̊ ɴ		
Stop	p b	p̪ b̪	t̪ d̪		t d		ʈ ɖ		c ɟ	k g	q ɢ	ʔ	ʔ
Sibilant affricate					ts dz	tʃ dʒ	ʈʂ ɖʐ	tɕ dʑ					
Non-sibilant affricate	pɸ bβ	pf bv		tθ dð	tθ̪ dð̪	t̪θ̪ d̪ð̪	ʈʂʰ ʈʂʼ ɖʐ		cç ɟʝ	kx gɣ	qχ ɢʁ	ʔħ ʕʕ	ʔh
Sibilant fricative					s z	ʃ ʒ	ʂ ʐ	ɕ ʑ					
Non-sibilant fricative	ɸ β	f v	θ̪ ð̪	θ ð	θ̪ ð̪	ɹʰ ɹʼ			ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Approximant		ʋ ð̞			ɹ		ɻ		j ɰ	ɥ w			ʔ
Flap or tap	ⱱ	ⱱ	ɾ̪		ɾ ɽ		ɽ ɭ̆				ɢ̆	ʡ̆	
Trill	ʙ		r̪		r ɽ		ɽ ɭ				ʀ̥ ʀ	ʜ ʢ	
Lateral affricate					tɬ dɮ		ʈɭʼ		cʎʼ	kʟ̝ gʟ			
Lateral fricative					ɬ ɮ		ɭʼ		ʎʼ ʎ̥ʼ	ʟ̝ ʟ			
Lateral approximant			l̪		l		ɭ		ʎ	ʟ	ʟ		
Lateral flap			ɺ		ɾ		ɽ		ʎ̆	ʟ̆			

Linguistic typology example: numerals

Feature 131A: Numeral Bases



Values

Decimal	125
Hybrid vigesimal-decimal	22
Pure vigesimal	20
Other base	5
Extended body-part system	4
Restricted	20

THE WORLD ATLAS
OF LANGUAGE STRUCTURES
ONLINE

wals.info/chapter/131

WALS

THE WORLD ATLAS OF LANGUAGE STRUCTURES ONLINE

wals.info

- 2,676 languages, 192 attributes

ID#	Feature Name	Category	Feature Values
1	Consonant Inventories	Phonology (19)	{1:Large, 2:Small, 3:Moderately Small, 4:Moderately Large, 5:Average}
23	Locus of Marking in the Clause	Morphology (10)	{1:Head, 2:None, 3:Dependent, 4:Double, 5:Other}
30	Number of Genders	Nominal Categories (28)	{1:Three, 2:None, 3:Two, 4:Four, 5:Five or More}
58	Obligatory Possessive Inflection	Nominal Syntax (7)	{1:Absent, 2:Exists}
66	The Perfect	Verbal Categories (16)	{1:None, 2:Other, 3:From 'finish' or 'already', 4:From Possessive}
81	Order of Subject, Object and Verb	Word Order (17)	{1:SVO, 2:SOV, 3:No Dominant Order, 4:VSO, 5:VOS, 6:OVS, 7:OSV}
121	Comparative Constructions	Simple Clauses (24)	{1:Conjoined, 2:Locational, 3:Particle, 4:Exceed}
125	Purpose Clauses	Complex Sentences (7)	{1:Balanced/deranked, 2:Deranked, 3:Balanced}
138	Tea	Lexicon (10)	{1:Other, 2:Derived from Sinitic 'cha', 3:Derived from Chinese 'te'}
140	Question Particles in Sign Languages	Sign Languages (2)	{1:None, 2:One, 3:More than one}
142	Para-Linguistic Usages of Clicks	Other (2)	{1:Logical meanings, 2:Affective meanings, 3:Other or none}

Example from Georgi, Xia and Lewis (2010)

Dryer, Matthew S. & Haspelmath, Martin (eds.) 2013.
The World Atlas of Language Structures Online.
Leipzig: Max Planck Institute for Evolutionary Anthropology.

Automatic prediction of typological features

- Morphosyntactic annotation projection
  - Sentence and treebank alignments to project feature annotations from similar languages
- Unsupervised and semi-supervised feature propagation
  - Hierarchical typological clustering and majority value assignment
  - Language-family based nearest neighbor projection
  - Matrix completion
- Supervised Learning
  - Logistic regression
  - Determinant point process with neural features
- Cross-lingual distributional feature alignment

Ponti, E.M., O'horan, H., Berzak, Y., Vulić, I., Reichart, R., Poibeau, T., Shutova, E. and Korhonen, A., 2019. Modeling language variation and universals: A survey on typological linguistics for natural language processing. *Computational Linguistics,* 45(3), pp.559-601.

TyP-NLP Workshop at ACL 2019

Typological databases

Name	Levels	Coverage	Feature Example
World Atlas of Language Structures (WALS)	Phonology, Morphosyntax, Lexical semantics	2,676 languages; 192 attributes; 17% values covered	ORDER OF OBJECT AND VERB Amele: OV (713) Gbaya Kara: VO (705)
Atlas of Pidgin and Creole Language Structures (APiCS)	Phonology, Morphosyntax	76 languages; 335 attributes	TENSE–ASPECT SYSTEMS Ternate Chabacano: purely aspectual (10) Afrikaans: purely temporal (1)
URIEL Typological Compendium	Phonology, Morphosyntax, Lexical semantics	8,070 languages; 284 attributes; ~439,000 values	CASE IS PREFIX Berber (Middle Atlas): yes (38) Hawaaian: no (993)
Syntactic Structures of the World's Languages (SSWL)	Morphosyntax	262 languages; 148 attributes; 45% values covered	STANDARD NEGATION IS SUFFIX Amharic: yes (21) Laal: no (170)
AUTOTYP	Morphosyntax	825 languages; ~1,000 attributes	PRESENCE OF CLUSIVITY !Kung (Ju): false Ik (Kuliak): true
Valency Patterns Leipzig (ValPaL)	Predicate–argument structures	36 languages; 80 attributes; 1,156 values	TO LAUGH Mandinka: 1 > V Sliammon: V.sbj[1] 1
Lyon–Albuquerque Phonological Systems Database (LAPSyD)	Phonology	422 languages; ~70 attributes	ɗ AND ɮ Sindhi: yes (1) Chuvash: no (421)
PHOIBLE Online	Phonology	2,155 languages; 2,160 attributes	m Vietnamese: yes (2053) Pirahã: no (102)
StressTyp2	Phonology	699 languages; 927 attributes	STRESS ON FIRST SYLLABLE Koromfé: yes (183) Cubeo: no (516)
World Loanword Database (WOLD)	Lexical semantics	41 languages; 24 attributes; ~2,000 values	HORSE Quechua: *kaballu* borrowed (24) Sakha: *silgi* no evidence (18)
Intercontinental Dictionary Series (IDS)	Lexical semantics	329 languages; 1,310 attributes	WORLD Russian: *mir* Tocharian A: *ārkiśoṣi*
Automated Similarity Judgment Program (ASJP)	Lexical semantics	7,221 languages; 40 attributes	I Ainu Maoka: *co7okay* Japanese: *watashi*

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URIEL

- URIEL typological compendium
  - Phonology, morphosyntax, lexical semantics
  - 8.070 languages, 284 attributes, $439,000 values
- `lang2vec` representations from URIEL

  https://pypi.org/project/lang2vec/

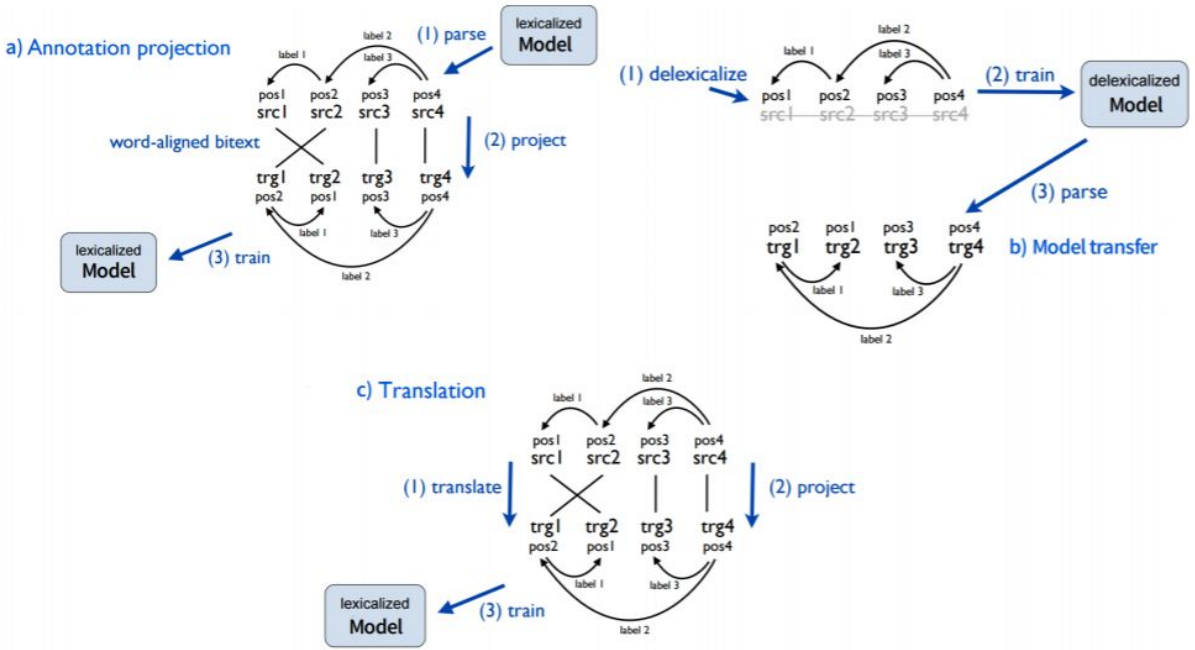
Littel, Patrick, David R. Mortensen, and Lori Levin. 2017. URIEL Typological database. *In* Proc. EACL

Malaviya, C., Neubig, G. and Littell, P., 2017. Learning language representations for typology prediction. *In* Proc. EMNLP

Linguistic universals

- All languages have vowels and consonants
- All (or at least nearly all) languages of the world also make a distinction between nouns and verbs

Linguistic typology in NLP



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Open research problems

- how to extract typological features automatically from existing multilingual resources such as Universal Dependency treebank, UniMorph, Wikipedia, or Bible corpora
- how to accurately predict typological knowledge while controlling for genealogical and areal biases
- how to incorporate linguistic typology into models
- how to alleviate negative transfer and catastrophic forgetting in multilingually trained models using typological knowledge

Further readings

- Survey:

  Ponti, E.M., O'horan, H., Berzak, Y., Vulić, I., Reichart, R., Poibeau, T., Shutova, E. and Korhonen, A., 2019. Modeling language variation and universals: A survey on typological linguistics for natural language processing. *Computational Linguistics,* 45(3), pp.559-601.

- Papers in tracks on morphology/phonology or multilinguality at *CL conferences
- Workshops: SIGMORPHON, SIGTYP, ComputEL, AfricaNLP, DeepLo, etc.

Class reading and discussion

- Reading
  - Lin, Y.H., Chen, C.Y., Lee, J., Li, Z., Zhang, Y., Xia, M., Rijhwani, S., He, J., Zhang, Z., Ma, X., Anastasopoulos, A., Littell, P. and Neubig, G. 2019. Choosing Transfer Languages for Cross-Lingual Learning. In Proc. ACL. https://arxiv.org/pdf/1905.12688.pdf
- Discussion question