CENTRE FOR TRANSLATION STUDIES at the University of Leeds

Development and evaluation of phonological models for cognate identification

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Approach

- Cognate identification important for Machine Translation (MT) & CAT:
  - Building cognate term-banks from comparable corpora;
  - Lexicon for closely-related & under-resourced languages;
  - Additional data source for statistical sentence alignment, etc…
- Current methods rely on character-based distances (e.g., Levenshtein)
  - Count insertions, deletions, substitutions of characters;
  - Treat each character as an ‘atomic’ unit without structure;
  - Difficult to apply across different scripts (need transliteration).
- Solution: phonological features of characters to calculate similarity
  - Characters mapped to sets of distinctive acoustic features;
  - Used in historical linguistics and dialectological studies;
  - Applied to cognate identification for MT (cf. Babych, 2016).

Graphemic-Phonological features
Uk: “*жовтий*” (*zhovtyj*) = ‘yellow’

ж (zh) 'type:consonant', 'voice:ff-voiced', 'maner:ff-fricative', 'active:ff-fronttongue', 'passive:ff-palatal'
о (o) **'type:vowel'**, **'backness:back', 'height:mid'**, **'roundedness:rounded'**, 'palate:nonpalatalizing'
в (v) **'type:consonant'**, 'voice:fl-voiced', 'maner:fl-fricative', 'active:fl-labial', 'passive:fl-bilabial'
т (t) 'type:consonant', 'voice:pf-unvoiced', 'maner:pf-plosive', 'active:pf-fronttongue', 'passive:pf-alveolar'
и (y) **'type:vowel'**, 'backness:front', **'height:closemid'**,**'roundedness:unrounded'**, **'palate:nonpalatalizing'**
й (j) 'type:consonant', 'voice:xm-sonorant', 'maner:xm-approximant','active:xm-midtongue', 'passive:am-palatal'

Feature representations for corresponding characters in Ru: “*жёлтый*” (*zheltyj*) = ‘yellow’.

ё (io) **'type:vowel', 'backness:back', 'height:mid', 'roundedness:rounded'**, 'palate:palatalizing'
л (l) **'type:consonant'**, 'voice:lf-sonorant', 'maner:lf-lateral', 'active:lf-fronttongue', 'passive:lf-alveolar'

ы (y) **'type:vowel'**, 'backness:central', **'height:closemid','roundedness:unrounded', 'palate:nonpalatalizing'**

Calculation of the Phonological Levenshtein for Uk “*жовтий*” (*zhovtyj*) = ‘yellow’ and Ru “жёлтый” (zheltyi) = ‘yellow’:

0.0	1.0	2.0	3.0	4.0	5.0	6.0
1.0	**0.0**	1.0	2.0	3.0	4.0	5.0
2.0	1.0	**0.2**	1.2	2.2	3.2	4.2
3.0	2.0	1.2	**1.0**	2.0	3.0	4.0
4.0	3.0	2.2	2.0	**1.0**	2.0	3.0
5.0	4.0	3.2	3.0	2.0	**1.2**	2.2
6.0	5.0	4.2	4.0	3.0	2.2	**1.2**

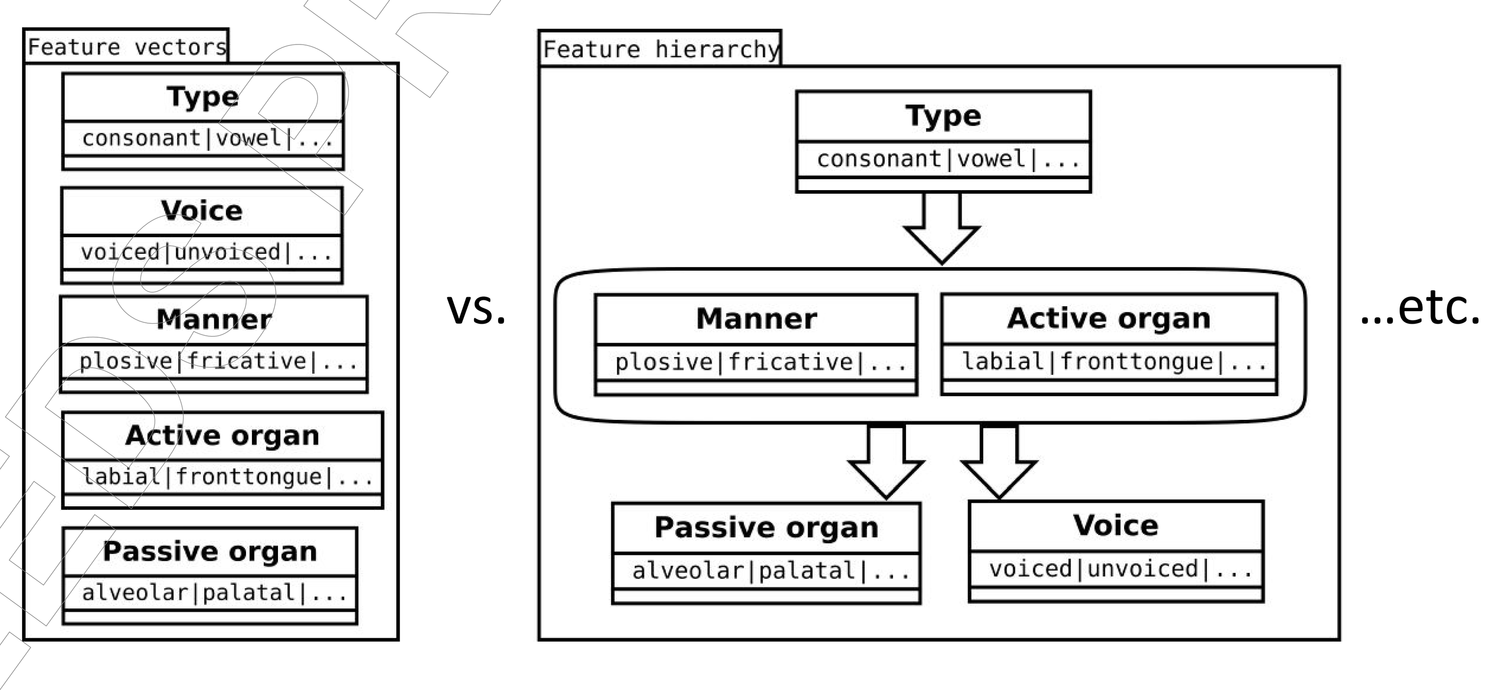
cf.: Metric calculated for Uk “*жовтий*” (*zhovtyj*) = ‘yellow’ with Ru “*жуткий*” (*zhutkij*) = ‘dismal’:

0.0	1.0	2.0	3.0	4.0	5.0	6.0
1.0	**0.0**	1.0	2.0	3.0	4.0	5.0
2.0	1.0	**0.2**	1.2	2.2	3.2	4.2
3.0	2.0	1.2	**1.0**	1.2	2.2	3.2
4.0	3.0	2.2	2.0	**1.8**	2.2	3.0
5.0	4.0	3.2	3.0	2.8	**2.0**	3.0
6.0	5.0	4.2	4.0	3.8	3.0	**2.0**

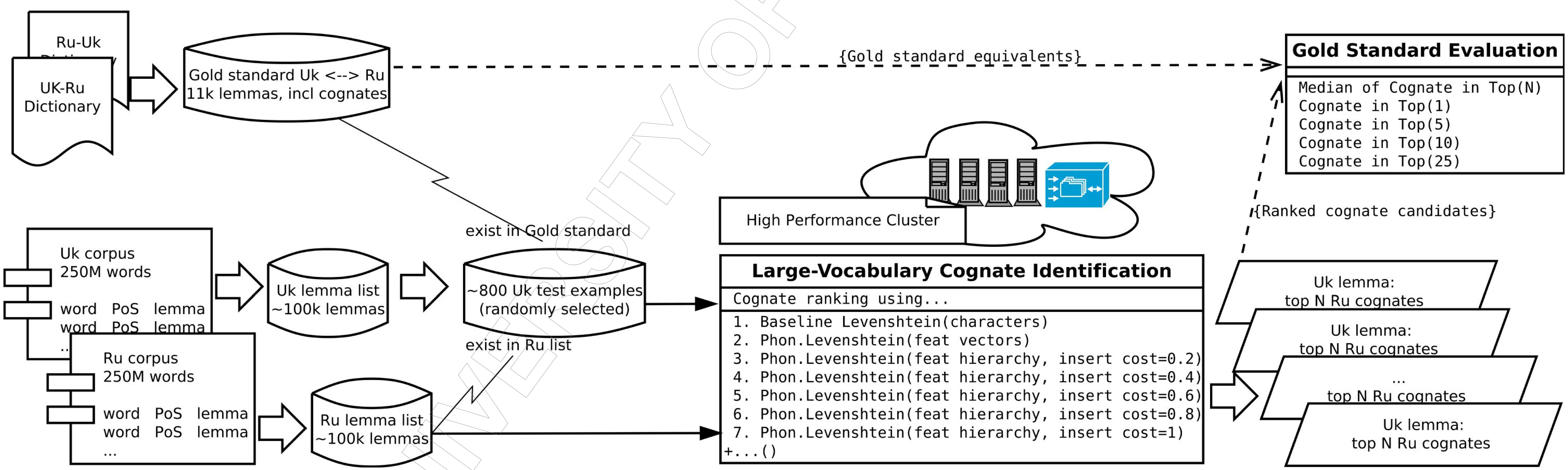
Problems and solutions

- Large-vocabulary cognate identification ≠ historic linguistic studies
  - False positives due to many more plausible alternatives;
  - In pilot: phonological feature vectors degraded performance;
  - Baseline character-based Levenshtein more resistant to errors.
- Some errors of Phonological Levenshtein metric due to imbalanced cost of insertion/deletion vs. substitution, e.g., for 5 phonological features:
  - Typical substitution cost for unrelated consonants = 0.8;
  - The insertion/deletion cost = 1.0 leads to under-generation of cognates with inserted/deleted characters.
- We need a systematic way for development and evaluation of alternative feature models, arrangements and edit costs

  (an automated framework for phonological feature engineering):



Development and evaluation framework for phonological models



Evaluation results

Experiment	Median top N	Top 1	Top 5	Top 10	Top 25
Baseline Char.Lev	50	206	328	360	382
Phon.Lev FeatVectors	87.5	**215**	289	319	349
Diff with Base L	-75%	+4.4%	-10%	-11%	-9%
Phon.Lev Hierarchy:					
Phon.LevH i=0.2	125.5	216	291	315	342
Phon.LevH i=0.4	54.5	230	307	334	367
Phon.LevH i=0.6	*48*	235	328	354	385
Phon.LevH i=0.8	**40**	**240**	**337**	**359**	**391**
Phon.LevH i=1.0	47.5	**240**	334	359	385
Best Improv. over BaselL	**+20%**	**+16.5%**	**+3%**	**0%**	**+2%**

Conclusions

- Hierarchical phonological models improve accuracy of large-vocabulary cognate identification up to 20% on Top-N measures.
- Evaluation and development framework for phonological models:
  - Allows for accurate feature calibration and parameter setting;
  - Enables a systematic task-based feature engineering.
- Potential applications of the models beyond cognate identification:
  - Interlingual transliteration via common phonological space;
  - Character-based models for Neural MT;
  - Morphology induction & morphological variation modelling.
- Future work: evaluating alternative feature topologies, integrating statistical and semantic filters for cognate identification.
- Phonological models and resources (feature sets + scripts) released on https://github.com/bogdanbabych/cognates-phonology